Volume 23, number 1

JANUARY, 1956

G.E.C. JOURNAL

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COVER PICTURE

25 MW alternators in the Tungatinah Power Station of the Hydro-electric Commission of Tasmania

Published by
THE GENERAL ELECTRIC CO. LTD.
Magnet House, Kingsway, London, W.C.2

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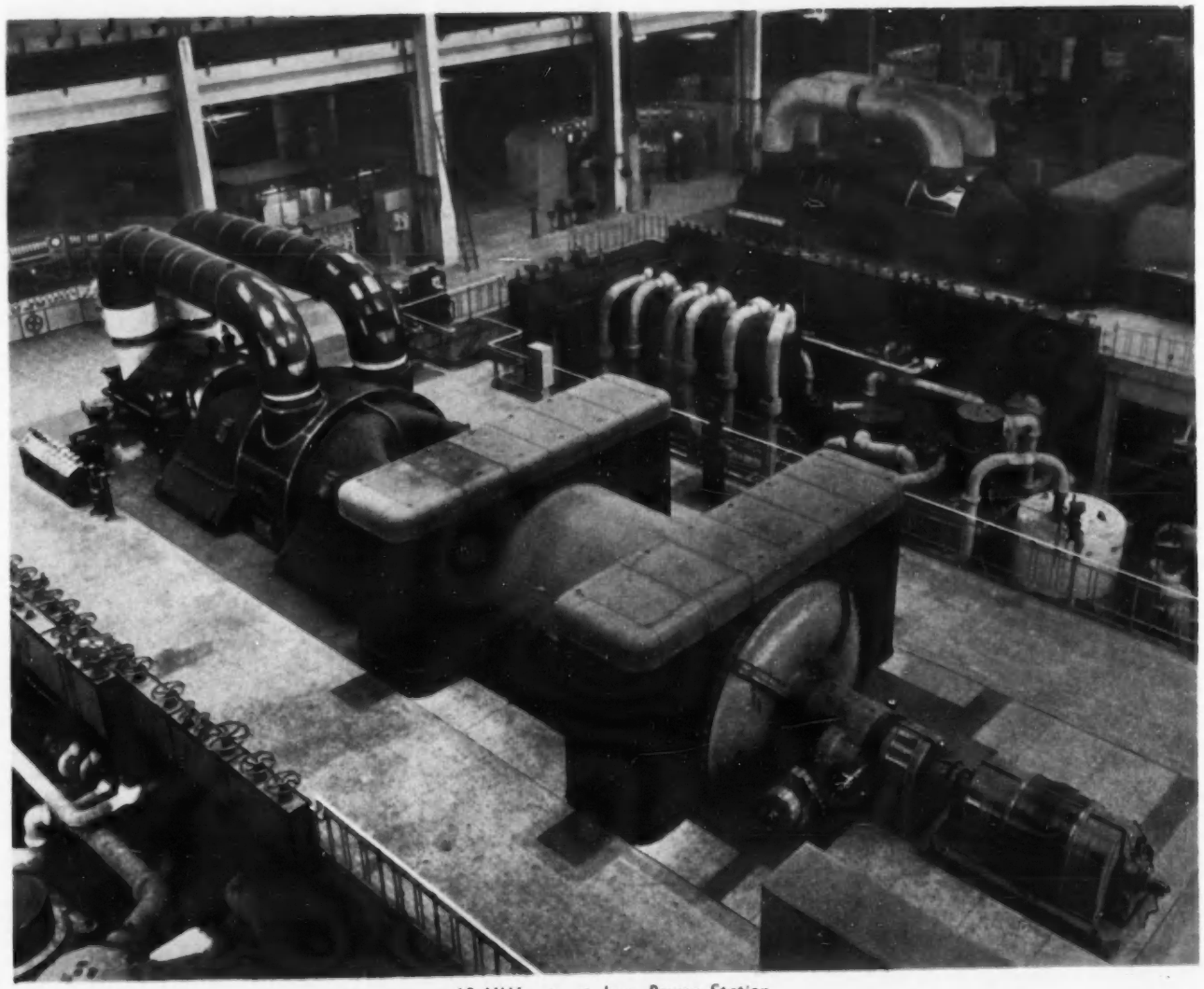


60 MW sets at Ince Power Station

Progress 1955

Power Equipment

STEAM TURBO-GENERATORS.

The total capacity of plant commissioned during 1955 has again exceeded that of any previous year. This total of approximately 410 MW includes several 60 MW and 30 MW sets for the Central Electricity Authority; and about a quarter of the total is represented by plant commissioned overseas. At the Ince Power Station three sets have been commissioned and the fourth set for this station is about to be delivered (frontispiece).

Overseas, this year has seen the completion also of the Orlando Power Station, Johannesburg, where ten sets totalling 337·5 MW are in service. Two 10 MW sets have been commissioned at Bloemfontein and a 60 MW turbo-generator delivered for the Electricity Supply Commission of South Africa, Wilge Power Station, will soon be in service (fig. 2).

The record volume of plant commissioned is matched by new orders received totalling 904 MW. Of this total, 600 MW are for the Central Electricity Authority, comprising three 120 MW sets for North-

Fig. 1.—The 125 MW hydro-electric station at Tungatinah, Tasmania, seen from the wooded slopes of the Nive River Valley.

fleet, two 60 MW sets for Poole, and one 60 MW set for Staythorpe, later transferred to Bold, and a further set for Bold. A significant contribution to the steam turbo-generating plant total this year is the 260 MW of combined steam and electrically driven compressor plant referred to later.

Further instructions have been received from the C.E.A. covering the Authority's projected Northfleet Power Station.

Last year the comprehensive contract was announced for the whole of the power plant and services to the £20,000,000 iron and steel project for Colvilles Limited, Ravenscraig, Motherwell. Fig. 3 shows the power house, just sixteen months after the order, wherein four turbines driving generators, blowers and pumps are at present under erection and three more nearing completion in the shops. The boilers, switchgear, transformers, cabling and

Fig. 2.—A 60 MW set in course of erection at Wilge Power Station, South Africa.

The first set, ordered early in 1955 and mentioned above, has been supplemented by two further sets in the present programme and will be followed by three more sets in the ultimate programme, to give a total station capacity of 720 MW.

In each case the contract includes the condensing and feed heating plant, and the second and third sets bring the total plant ordered during the year to 904 MW.

Orders for machines of smaller ratings include four pumping sets for Sydney Water Board, and sets for paper mills, coke oven plants and marine auxiliaries ; also eight 1,000 kW turbo-generators for the Admiralty.

cooling towers are all proceeding in accordance with the planned commissioning date later this year.

The outstanding thermal performance recorded at the Uskmouth Station has been supported by further tests at Ince where in both cases the sets were well within the heat consumption guarantees. The record performance obtained at maximum rating was 9,005 B.Th.U.'s per kWhr. on the standard conditions. These sets are all designed for an initial steam pressure of 900 p.s.i.g. and a temperature of 900 deg. F.

Special interest attaches to the 120 MW turbo-generator now under construction for C.E.A. Northfleet Power Station. The turbine is designed for

a reheat cycle with standard operating conditions of 1,500 p.s.i.g., 1,000 deg. F. with reheat 1,000 deg. F. and final feed temperature 435 deg. F. in six stages of feed heating. It is arranged in three casings—H.P., I.P. and L.P.—with solidly-coupled rotors throughout and a single thrust bearing for the complete set.

The H.P. turbine has four radial steam inlets with piston ring type joints into an inner casing containing the full pressure. The steam passes in a single flow through this turbine, in which the rotor is a solid forging. Established features of riveted blade fixation and vernier type glands and interstage packings are retained, special attention having been given to the latter to avoid local shaft heating in the event of an accidental " touch ". The blading is of vortex design throughout.

The steam, after reheating, enters the I.P. cylinder, again with radial pipes to ensure symmetrical heating. The I.P. rotor is also a single forging and in this the steam is expanded down to approximately 40 p.s.i.a.

The L.P. turbine is also arranged with a double casing. The inner casing, which contains the four double-flow L.P. stages, is centrally located and supported within an outer casing comprising a single vacuum shell. The latter is a very heavy fabricated structure for the bottom half with cast-steel top half covers. The particular feature of this design is the extreme rigidity of support given to the most heavily-loaded bearings, achieved by reinforced concrete walls placed transversely across the set on either side of the single-shell condenser. This avoids any steelwork or concrete being required as a bridge across the condenser, and the bottom half exhaust casing itself forms a double girder of immense strength on which the major portion of the condenser weight is hung. Thus there is no disturbance to the alignment of the set by variation in deflections caused by opening a half section of the condenser for cleaning.

It will be noted that all vacuum joints are steel-to-

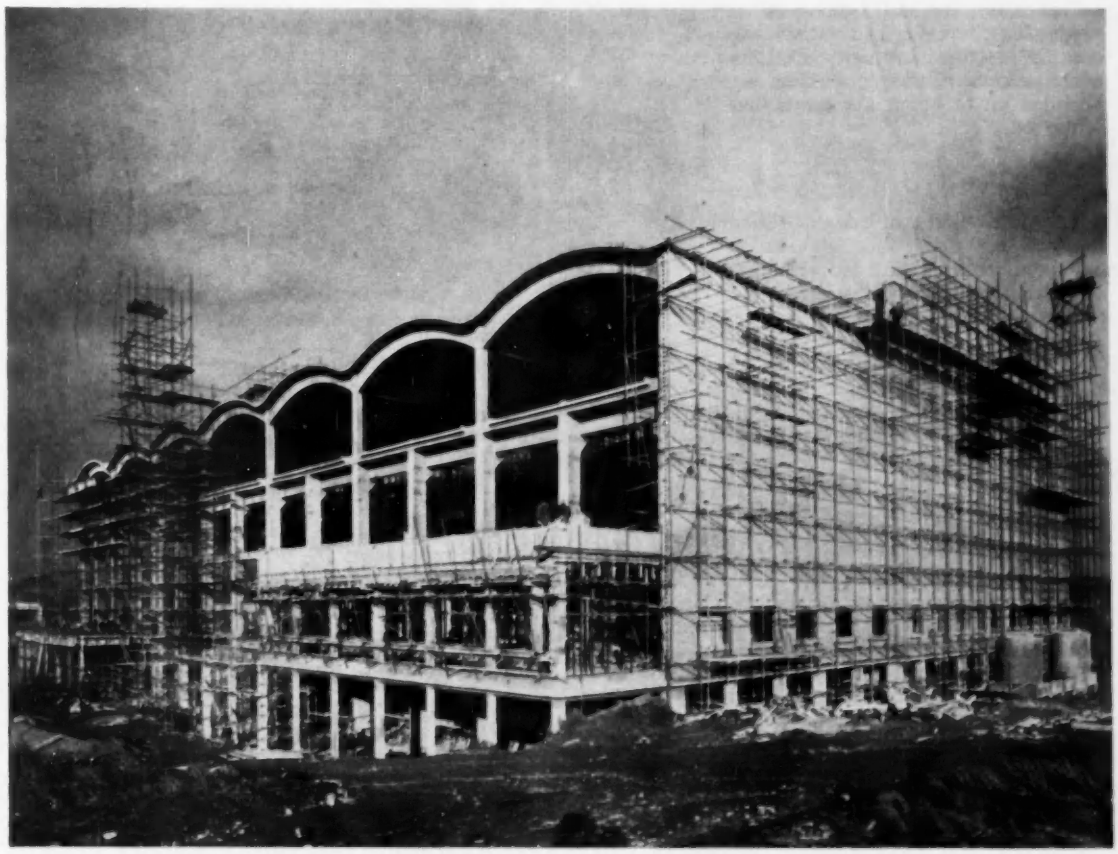


Fig. 3.—The power house for Colvilles Ltd. at Ravenscraig, Glasgow, part of the G.E.C. comprehensive contract.

steel and the turbo exhaust flange and condenser joint are seal-welded.

The last stage blades are 27 in. long and in accordance with previous practice are provided with cover bands and a multiple prong root and riveted fixation. This is regarded as the best form of blade system and the cover band is unique both in its design and its adoption for blading of such high peripheral speed.

Particular care has been paid to supporting the casings in such a way that the axial concentricity is maintained and free sliding surfaces are provided on or about the centre line of the set.

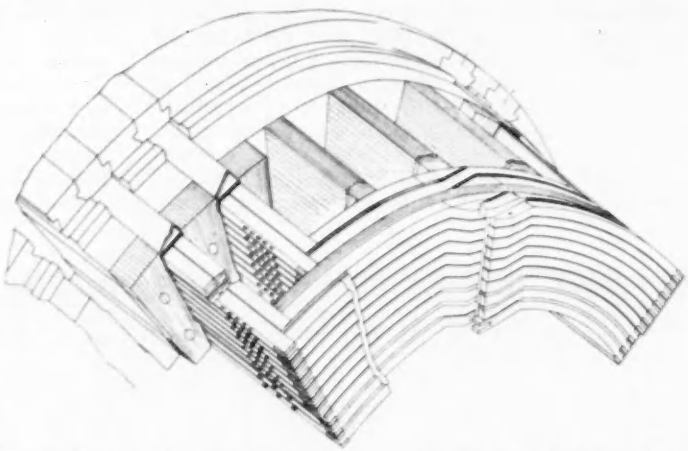


Fig. 4.—End view of two rotor coils, showing cross connections and gas ports in the conductors.

DEVELOPMENT.

The development of designs during the year for turbines of large rating has been accompanied by the new considerations necessary to meet the vast new air compressor field described below.

This work has been supported by detailed investigations of governors, and proof material testing in support of blade fixation for blades of extreme length and stress; also unique shrouding developments. The established blade vibration investigations continue with the latest designs.

It is always invaluable to have full-scale test support for research data and design calculations and a special test of this nature which has been conducted is worthy of comment. It was made possible by the new shop facilities available at Erith and a 90,000 c.f.m. turbo-blower being available many months before it was required on site. This test, which was made for the dual purpose of obtaining the air duty and characteristics over a wide range of speed and various diffuser angles, also performance data on a prototype cooler, was conducted at full volume under closed circuit conditions through some 200 ft. of 3 ft. 6 in. dia. air trunking. The steam consumption and turbine performance were checked simultaneously. Such results are of immense benefit in establishing data for development of new designs.

During the year much development work has been completed on direct cooling of the rotors of large alternators in order to improve the dissipation of heat from the rotor windings. The design produced formed the subject of an article in a previous issue of this journal (*G.E.C. Journal*, Vol. XXII, No. 3, pp. 155-160, July, 1955). It will be recalled that an essential feature of the design is the use of straight rectangular tubes for the slot portions of the rotor windings, ventilated on a separate circuit from that of the stator, the hydrogen being circulated through the tubes by a centrifugal impeller mounted on the outboard end of the rotor.

The rotor conductors are connected at both ends by suitably shaped copper strips which are also cooled on separate circuits, the general arrangement of the rotor winding being shown in fig. 4. In addition to providing efficient heat dissipation, the design also lends itself to a sound practical construction which has many advantages over the normal method of winding. It permits an appreciable reduction in frame size to be made and raises the maximum output of a single unit running at 3,000 r.p.m. to a figure in excess of 200 MW. Stator weights and overall lengths of the sets are reduced, thereby easing transport problems and handling on site.

Tests on a prototype winding have already established the soundness of the design. In these tests, which have continued night and day, the windings have been subjected to automatically controlled thermal cycles of less than 15 minutes each, a typical cycle being shown in fig. 5. After completing over

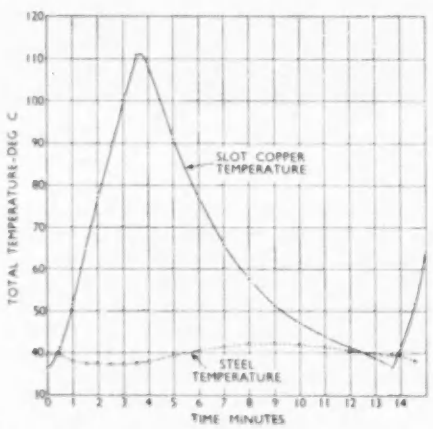


Fig. 5.—Typical thermal cycle during initial test.

2,000 cycles at copper temperatures up to 170 deg. C., the windings were removed from the slots so that a complete examination of the insulation could be made. Subsequently the coils were replaced, using the original insulation in some of the slots, but alternative material was used in other slots to provide data on comparative performance. The tests already completed, assuming two-shift working and using the normal method of assessing short time ageing tests, represent a running period of the order of 40 years at normal operating temperatures.

CENTRIFUGAL AIR COMPRESSORS.

A compressed air installation believed to be the largest in the world is now under construction to the order of the Ministry of Works. This results from the new field of aeronautical research demanded by the rapid development of aircraft turbo-jet engines, air-frames and ram jets. Such research and routine testing require large masses of air moved by compressors through closed circuit wind tunnels or test cells in open circuit, either at high pressures or under sub-atmospheric conditions where the compressors are connected as exhausters discharging to the atmosphere.

The lead the Company has taken in this respect is notable. The single installation referred to totals 352,000 h.p.—four times the size of any other installations in operation or under construction in this country—and it is believed to exceed by some 60,000 h.p. any other single installation in the world of this class of plant.

Fig. 6 is an impression of one of the eight sets forming this installation. Although this is unique in form and usage it consists basically of centrifugal compressors, turbines and synchronous motors conforming to established standards. The proved reliability in service of turbine-driven uncooled centrifugal compressors (designated "blowers" in blast furnace usage) led naturally to the choice of these robust machines to meet the stringent and variable duties of test plant service.

All the eight identical sets are connected by air mains and valves either severally or in unison according to the test requirements. Each set comprises the following machines coupled in line and operating at 3,000 r.p.m.: an 8,000 h.p. turbine, two L.P. centrifugal compressors, one H.P. centrifugal compressor and a 36,000 h.p. synchronous motor with exciter and a small high frequency generator for remote speed recording.

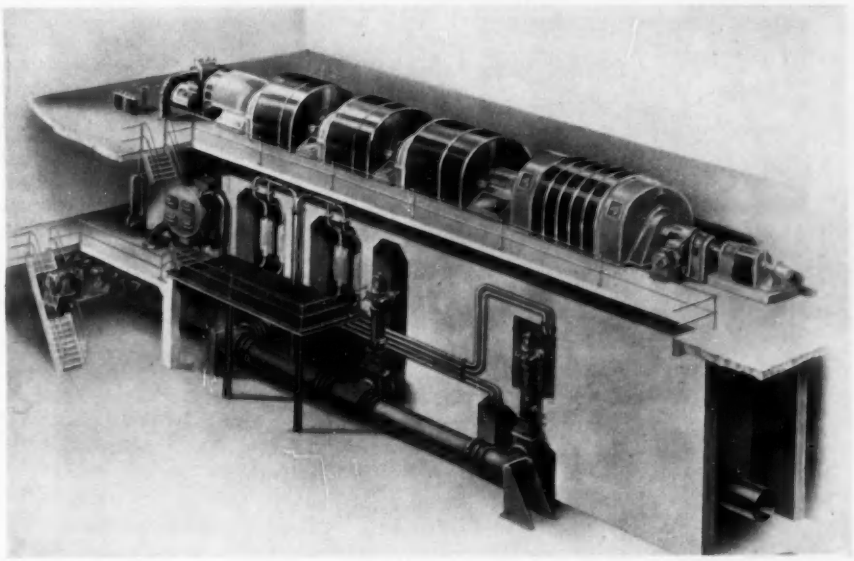


Fig. 6.—Perspective view of one of the eight sets comprising the 352,000 h.p. compressor plant for aeronautical research.

The principal function of the turbine is to start the set and enable the motor to be synchronised, thus avoiding the formidable problems involved with independent geared starting motors and the heavy current demands on the line in such arrangements. The total windage power requirement of the set at synchronising speed is nearly 6,000 h.p. and the good starting torque of the turbine is ideally suited to this service. The turbine has been rated at 8,000 h.p. with good efficiency to supplement economically the bulk of the power demand taken electrically.

Steam conditions at the turbine are 350 p.s.i.g., 625 deg. F. and the two-row velocity stage and sixteen impulse stages of the turbine give a consumption of

7.8 lb./B.H.P. hr. when exhausting into the surface condenser at 28 in. Hg. vacuum. These steam conditions are well suited to the turbine rating and test conditions requiring quick starting from cold and perhaps long periods of idling. Further, with this steam temperature no undue care in barring the set to ensure uniform heating is required thus increasing the service availability. Barring gear is fitted, however ; also jacking oil connections to the motor bearings as a facility for servicing in view of the size and weight of plant involved.

Naturally the focal point of each set is the compressor. This is in three casings, each so proportioned in compression ratio and characteristics that they match when operating in either series or parallel. steel. The compression is adiabatic but intercoolers are provided between the L.P. and H.P. machines and an aftercooler for adjustment of final temperature.

Each stage has polished aluminium diffuser blades carried in detachable plates within the diaphragm to facilitate a change of characteristic if required. In each case the discharge end casing is in one piece with the barrel, thus eliminating a vertical joint and bolting at the end subjected to high pressure and temperature.

All three coolers have two interchangeable nests but the casing of the H.P. is proportioned for the higher pressures. The tube nests contain Integron copper tubes and are arranged for an internal by-pass by means of motor-operated quadrant gates. Cooling water to these coolers is arranged as an integral system with the

Fig. 7.—Two compressors with geared synchronous motor drive installed at Mosley Common Colliery.

The air duty is 200 lb./sec. at 9·5 to 1 compression ratio with final temperature 480 deg. K., alternatively 270 lb./sec. at 3·32 to 1 compression ratio, 452 deg. K. Expressed otherwise, this represents 157,000 cu. ft. per min, at 140 p.s.i.g. discharge pressure ; or 212,000 cu. ft. per min, at 49 p.s.i.g. Total quantities are, of course, eight times the above.

When these compressors are connected for exhausting duties the inlet pressure is depressed to one-ninth atmospheric, while the sets are also designed for series working between themselves to handle the above volumes, creating one eighty-first part of atmospheric pressure at the suction, i.e. twice 9:1 compression ratio in series.

Each of the three compressors has four stages with impellers of about 60 in. diameter. The stages are generally similar in arrangement but the two L.P. casings are of cast iron while the H.P. casing is of cast

condenser connected in series and served by the same pump.

The synchronous motor follows the design of conventional air-cooled generating plant with closed circuit air cooler and is connected by a solid coupling to the H.P. compressor. The motor windings, designed for 11 kV, are directly connected to 33 kV/11 kV transformers, also supplied by the Company.

Control of these sets after initial starting operations on the turbine floor level is from a remote control room with centralised operation for all sets. During the period in which the sets are electrically connected to the line the speed is controlled by system frequency and the power output of the turbine is under direct control by remote positioning of the governing valves, the position of which is electrically relayed to an indicator calibrated to read the corresponding power. The compressors are arranged with Askania anti-

surge control gear both for series and parallel operation to prevent unnecessary electrical power swings.

Due to the high air temperatures and the alternative ductwork connections for series/parallel operation, also the test requirement of rapidly changing temperatures, great care has been taken to provide for the differential expansion of the air main connections and to position flexible joints in such a manner as to avoid unacceptable thrust. Sluice valves for the various air connections are all remotely operated from the control room. The discharge air main is of 6 ft. diameter with test pressure of 240 lb/sq. in. and contains a G.E.C. non-return valve with hydraulic damper gear based on the type used for blast furnace blowers.

Among more conventional plant of this nature commissioned this year are a turbine-driven 55,000 c.f.m. blower for Bairds, Gartsherrie Works; and two motor-driven compressors, each of 10,000 c.f.m. 80 p.s.i.g. duty, for the National Coal Board, Mosley Common Colliery (fig. 7). Each compressor in the latter installation is driven through speed-increasing gears by a 1,500 r.p.m. synchronous motor. The compressor is a new design which was described in an earlier Progress review (*G.E.C. Journal*, Vol. XXI, No. 1, pp. 4-6, January, 1954).

An order for three 4,200 h.p. synchronous motors, designed to run at 1,500 r.p.m. on an 11 kV supply has been received from the British Oxygen Co., Ltd. These machines will drive compressors with an output of 46,000 cu.m. per hour at a pressure of 5·1 kg/cm² absolute.

Fig. 8.—Metallurgical research in the new laboratories of the Atomic Energy Group.

ATOMIC ENERGY GROUP.

Towards the end of 1954 The General Electric Co. Ltd., and the three other principal electrical engineering companies in Great Britain, were invited by the Government to undertake a design study of the gas-cooled graphite-moderated thermal reactor. Each of the companies formed an association with a boiler manufacturer and in the case of The General Electric Co. Ltd. this association was formed with Simon-Carves Ltd., of Cheadle Heath.

The senior members of the teams set up by the four groups of companies were given six months intensive training by the United Kingdom Atomic Energy Authority at Harwell and at the group of factories controlled by the Industrial Group of the U.K.A.E.A. The completion of this training period coincided with the publication of the Government's White Paper—"A Programme of Nuclear Power"—in February, 1955. This programme proposed that the construction of the first two nuclear stations for the Central Electricity Authority should commence in the first quarter of 1957 and that 12 stations should be in commission by 1965. It was estimated that the combined capacity of these 12 stations would be between 1,500 and 2,000 MW, but subsequent developments now make it likely that their total capacity will be nearer 2,400 MW.

This programme gave the four groups a clearly defined target at which to aim, and they set about recruiting the staff necessary to undertake the complete design and construction of nuclear power stations costing somewhere in the region of £25,000,000 each.

The G.E.C.-Simon Carves group is located at Fraser & Chalmers Engineering Works. Most of its senior members have been drawn from the two companies but a number of specialists have been brought in from other sources. The group covers both design and development in its activities. In the design staff it has been necessary to include mechanical, electrical and civil engineers, chemical engineers, electronic engineers, nuclear physicists, mathematicians and metallurgists. On the development side, research has had to be conducted into the metallurgical properties of reactor constructional materials, fuel elements, moderators and coolants. In addition, heat transfer research has had to be conducted into fuel element and heat exchanger design. Extensive laboratories have been built (fig. 8) and the research programme, which covers future reactors as well as those at present

being designed, is now well under way. Provision has also been made for prototype units of mechanical and electrical equipment to be tested under reactor operating conditions in these laboratories. Research Laboratories, Witton and Salford Electrical Instruments are supporting the Group in their respective spheres.

A number of engineers, metallurgists and nuclear physicists from the Group and from the Research Laboratories are working on attachment within the United Kingdom Atomic Energy Authority's establishments.

The design of the first station is now in an advanced state and will be completed by the latter half of 1956.

Very close liaison is maintained between the group and the United Kingdom Atomic Energy Authority, which is acting as consultant to the Central Electricity Authority.

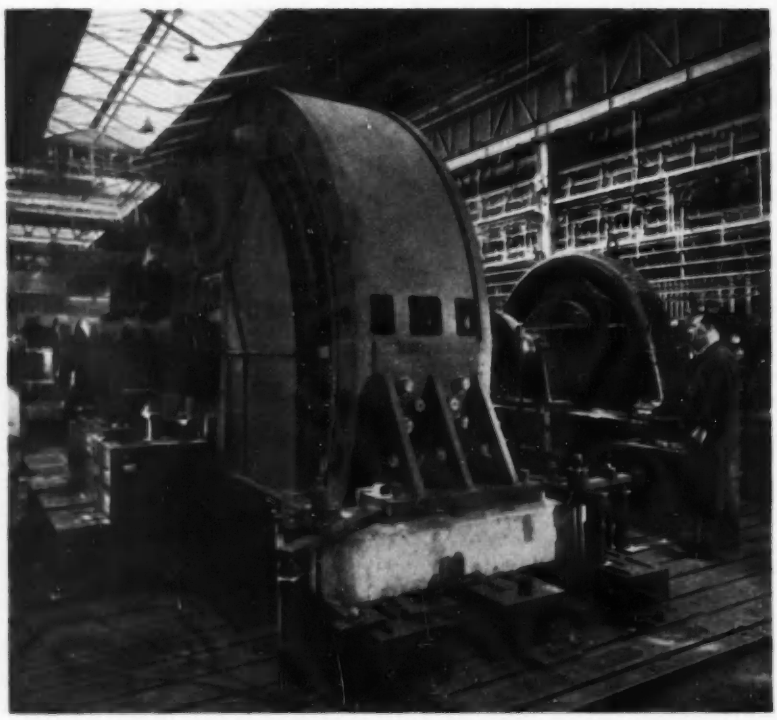


Fig. 9.—1,750 kW, 3·3 kV engine-driven alternator for Lake View & Star Mines, Western Australia, on the works test bed.

Gas Turbine and Diesel-driven Generators.

A considerable amount of engine-driven generating plant has been despatched overseas during the period under review. It includes two 900 kW sets and a 750 kW alternator, driven by a Ruston & Hornsby gas turbine, for Williamson Diamond Mines. This machine is designed for an overspeed of 2,000 r.p.m. For Lake View & Star Mines, Western Australia, a 1,750 kW, 3·3 kV alternator has been delivered. The alternator, which is seen on the works test bed in fig. 9, will be driven by a Crossley Premier *vis-a-vis* horizontal engine, the alternator being centrally disposed between two sections of the engine. This equipment is similar to plant built for the Bremang Gold Dredging Co., Ltd., provision being made for supporting the stator on rollers so that it can be barred round by means of a crane for inspection and maintenance purposes.

Also on order are sets ranging from 250 kW to 850 kW for Longreach Shire Council, Australia, Trinidad Sugar Estate, Suez Power Station and for export to Kanpur.

Hydro-Electric Plant.

The 62·5 MVA horizontal shaft alternator at Aura Kraftanlegg, Norway, was commissioned last August and is in full operation. The alternator, which is driven by an Escher Wyss pelton wheel, is one of the largest of its type running on the Continent. A general view of the set on the completion of erection

is shown in fig. 10. It is of interest to note that although this power station is built deep inside the mountains, windows in the walls of the generating room, combined with artificial lighting to simulate daylight, successfully give the illusion of open surroundings. Also for the Norwegian State Power Company, two 2·85 MVA alternators have been supplied.

tion of the internal machine angle and alarm features are provided so that, apart from its automatic function, the apparatus is of considerable assistance when the alternator voltage is under hand control.

Equipment of this design has been provided on two 60 MW sets at the Ince Power Station and the rapidity with which it will respond to changing requirements

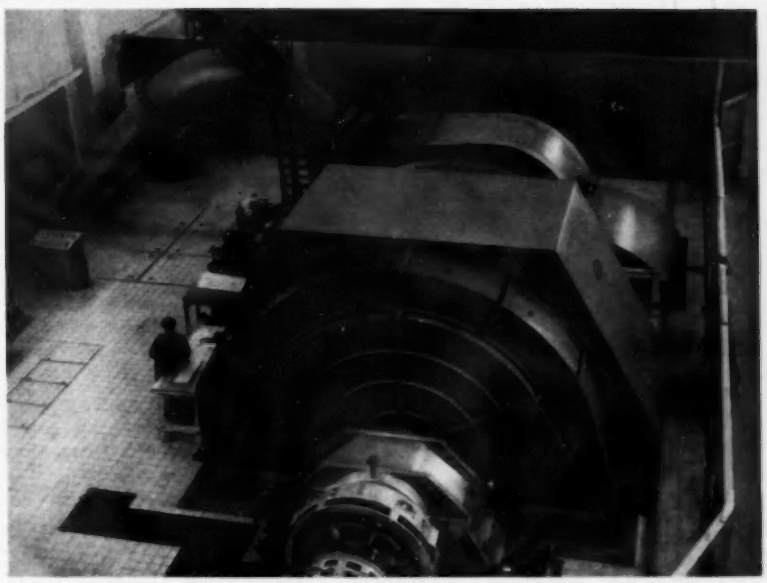


Fig. 10.—62·5 MVA horizontal shaft hydro-electric plant at Aura, Norway.

For service at the Kilembe Mines Ltd., Uganda, two 2·5 MVA alternators have been delivered. They are driven at 600 r.p.m. by Gilbert Gilkes & Gordon water turbines and generate at 3·3 kV. The 125 MW hydro-electric station at Tungatinah, Tasmania (fig. 1) is now in full operation.

LOW EXCITATION LIMITING EQUIPMENT FOR ALTERNATORS.

In an earlier review of progress (*G.E.C. Journal*, Vol. XXI, No. 1, pp. 6-7, January, 1954), attention was directed to the development of a low excitation limiting equipment which automatically ensures that alternator excitation cannot fall below the critical limit for stable operation. This device (fig. 11) detects any approach to instability by continuously measuring the internal machine angle (i.e. the angle between the terminal voltage vector and the vector representing the rotor pole axis). Its function is to promote an increase in excitation by automatically initiating a rapid adjustment of the voltage regulator immediately the internal machine angle exceeds the prescribed setting ; and to return the setting of the regulator gradually to normal as this angle again decreases. Direct continuous indica-

Fig. 11.—Low excitation limiting equipment showing the motor-driven rheostat and phase-shift unit.

of excitation was demonstrated during commissioning tests. Its use should enable the generating plant to be operated much nearer to its theoretical stability limit than has been possible hitherto.

TRANSFORMERS.

In connection with the contract placed by the Ministry of Works for air compressor plant of 352,000 h.p., eight 27·5 MVA, 33 kV transformers are being supplied. They are designed for forced oil circulation with water cooling, and each will supply a 36,000 h.p. synchronous motor which, together with a steam turbine, will drive one compressor (p. 7).

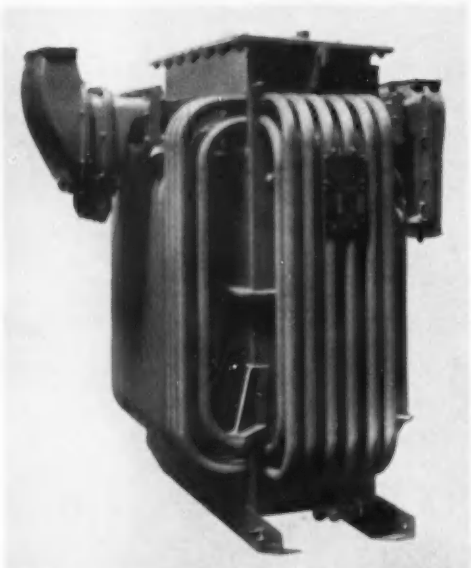


Fig. 12.—A 500 kVA transformer using cold rolled steel for the core.

A further four 16 MVA, 33 kV/11 kV transformers have been ordered by Colvilles Ltd., in connection with that company's £20 million iron and steel project at Motherwell. It will be recalled that a comprehensive contract covering a complete power station was placed by this steelworks and was summarised in the Progress review last year.

Of the orders received from overseas, particular interest attaches to that placed by the Metropolitano de Lisboa, S.A.R.L. for power supply, ventilating and pumping equipment for the first underground railway in Portugal, now under construction in Lisbon. These contracts, which were gained in the face of extreme Continental competition, are the only ones awarded to a British manufacturer. Four 750 kW rectifier transformers are included, two being connected delta/six phase and two star/six phase so that they will operate as two 1,500 kW, 12-phase equipments.

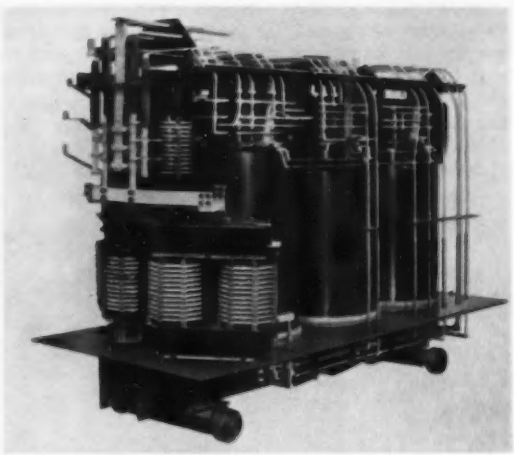


Fig. 13.—One of the ten 750 kW rectifier transformers for Moorgate Substation.

They will be hermetically sealed and filled with Pyroclor in order to afford maximum protection against fire risk.

During the period under review, some 300 MVA of transformers have been commissioned for the Central Electricity Authority, including generator-

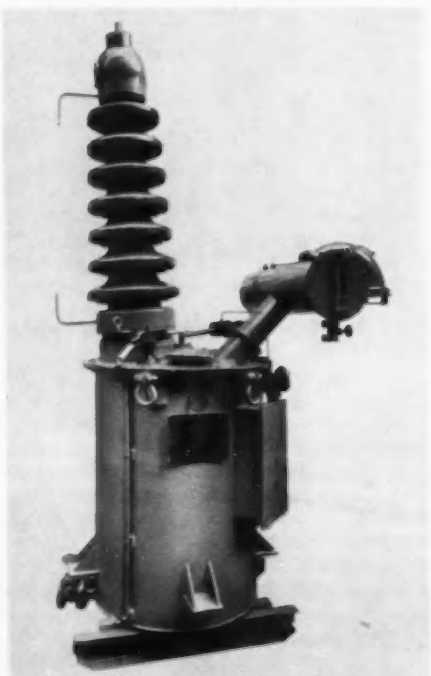


Fig. 14.—132 kV voltage transformer.

transformers rated at 72 MVA for the Uskmouth and Ince Power Stations, 36 MVA and 45 MVA units for Doncaster and Huncoat in addition to two 20 MVA transformers for Fawley and a number rated at 10 MVA for various substations. Also completed for the C.E.A. are two oil-immersed reactors to be installed at Rawtenstall. Each is designed for service on a 6·6 kV system and has a reactance of 6 per cent. with a throughput of 20 MVA, with a 5-sec. fault current rating of 29,200 A.

The first of ten 750 kW rectifier transformers for the Moorgate Substation of the London Transport Executive is now on site. These transformers (fig. 13) are similar to those in service at Surrey Docks Substation, in that they employ class "B" insulation and use a closed air circuit in conjunction with air-to-air heat exchangers for cooling.

Work completed for customers overseas includes a 7·5 MVA transformer for the Winnipeg Hydro Electric System, a number of units of various sizes totalling 50 MVA for India and one of 12·5 MVA for Calico Printers in Uganda.

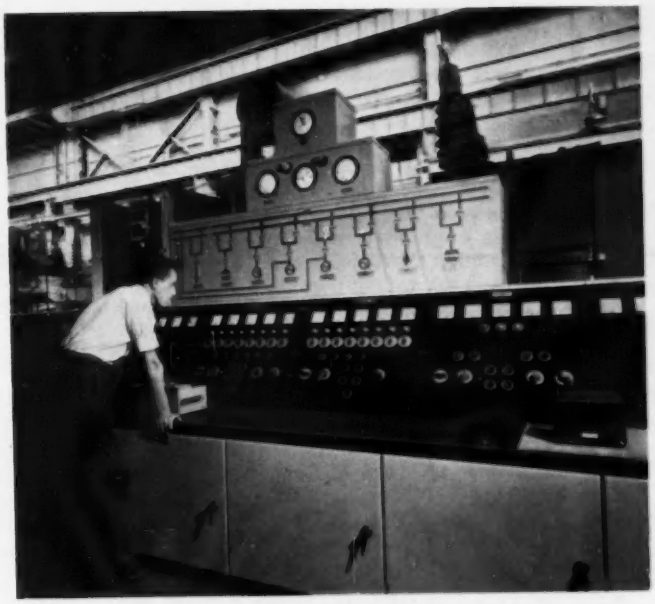


Fig. 16.—Control board for the test plant shown in fig. 15.

Fig. 15.—General view of the new test plant in the Transformer Works.

In the review of progress last year, attention was directed to the advantages which arise from using cold rolled steel for transformer cores. It will be recalled that in this technique the crystals are orientated so that the material is most readily magnetised in a direction parallel to the direction of rolling. Considerable progress has been made in the use of this material and a complete range of transformers to C.E.A. specification T.1 has been produced. These transformers are available for outputs up to 500 kVA at 11 kV, a 500 kVA unit being shown in fig. 12. This material is also being used for a number of 5,000 kVA transformers which are being built for the South Western Electricity Board.

pleted and the equipment (fig. 15) is now in service. The plant, which will give an output of over 26 MVA, includes two 10,000 kVA water cooled alternators, arranged to run in parallel with existing test plant and also with the 4,000 kVA machine in the substation of the Heavy Engineering Works. The centralised control board (fig. 16) includes a semaphore system to indicate the position of all associated oil circuit breakers.

OUTDOOR SWITCHGEAR.

The range of outdoor oil circuit breakers has been extended by the addition of a 500 MVA frame-mounted unit using a single tank. The breaker

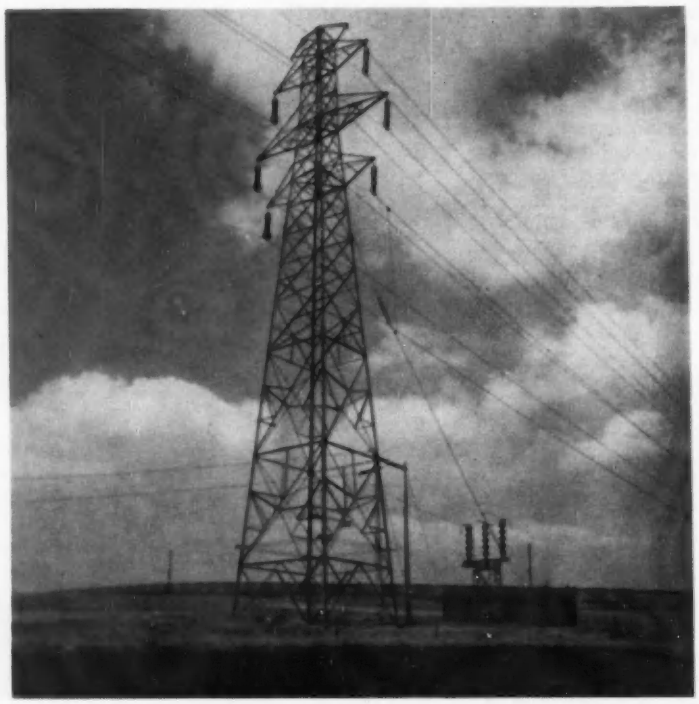


Fig. 17.—Connection to the 132 kV grid line at Witton for use in high-voltage line dropping tests.

For service in this country and overseas, thirty 132 kV voltage transformers (fig. 14) are in hand. These comply fully with British Standards Nos. 81 and 2046 and type tests have been completed including a 650 kV impulse test. The design incorporates two identical $110/\sqrt{3}$ V output windings which may be connected in parallel to increase the accuracy from Class B to Class A. Alternatively these windings may be used independently where transformers are required for protective as well as metering purposes.

The extensions to the Transformer Works test plant to which reference was made last year are com-

(fig. 18) is suitable for service on 11 kV and 15 kV systems, and has been designed primarily to meet the requirements of the Canadian market. These breakers will withstand an impulse voltage of 135 kV peak and are available for current ratings up to 2,000 A. They can be supplied for solenoid-operation or with hand-charged spring operating mechanisms.

The contacts, arc control pots and operating link mechanism are similar to those which have been standardised with marked success for indoor circuit breakers of corresponding ratings. Generous provision is made within the top cover to accommodate

Fig. 18.—11 kV, 500 MVA outdoor oil circuit breaker for currents up to 2,000 A.

current transformers. The tank is raised and lowered by a ratchet mechanism and wire ropes.

Reference has been made in previous reviews to progress in the development of outdoor oil circuit breakers of 2,500 and 3,500 MVA breaking capacity at 132 kV. The performance of a production sample of a 3,500 MVA breaker, demonstrated in the presence of officials of the Central Electricity Authority and consulting engineers, firmly established its satisfactory operation under conditions far more severe than those specified in British Standard No. 116/1952.

Facilities are now available for testing these breakers when breaking current at a leading power factor such as may occur when switching out unloaded transmission lines. The most satisfactory test is to use an actual transmission line and arrangements have been made with the Central Electricity Authority to use a 132 kV line which runs immediately behind the High Power Testing Station at Witton (fig. 17). During weekends a portion of the adjacent 132 kV network can be isolated from the remainder of the system and energised through a test circuit breaker from the generating and high voltage transformer plant of the Testing Station; the breaker can be operated to switch the line in or out and its performance recorded on low and high frequency oscillographs.

There has been a steady demand for outdoor circuit breakers both for home and overseas schemes. Of orders received for this country, the most important is that for fourteen 132 kV breakers rated at 3,500 MVA for the Willington substation near Derby. The contract covers also all the overhead conductors, isolators and surge diverters in addition to protective equipment and control panels. The substation will control six feeders linking Willington with Spondon, Allenton, Winster and Drakelow on the existing 132 kV grid system, and two feeders linking the new base-load generating station with the 275 kV supergrid.

Overseas contracts include all the equipment for the Roorkee Substation, India, where five 132 kV, 1,500 MVA and ten 66 kV, 500 MVA outdoor oil circuit breakers are to be installed. Other 66 kV breakers include ten for transmission developments in Australia.

For the 275 kV supergrid, the three-phase isolators at the Drakelow substation are in service (fig. 19),

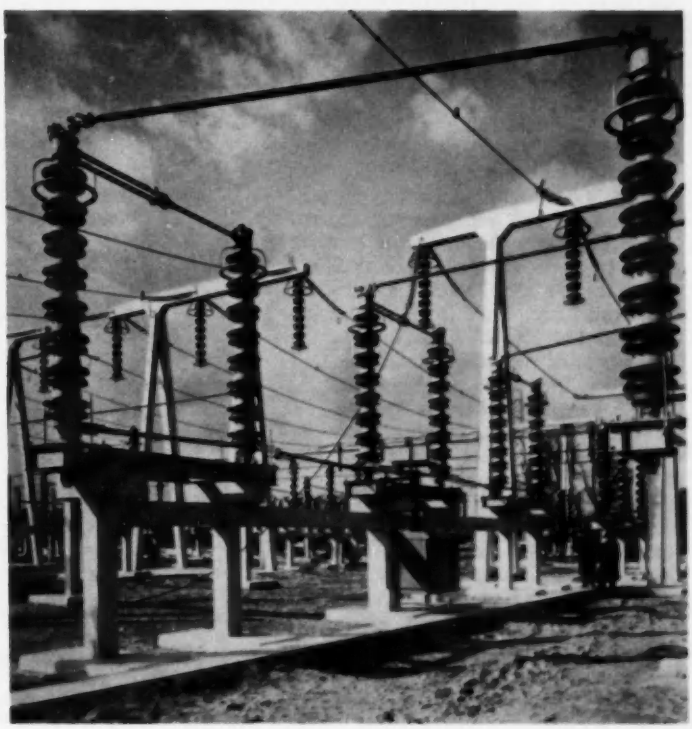


Fig. 19.—275 kV rotary isolators at Drakelow substation.

Fig. 20.—Part of the 11-panel, 33 kV, 750 MVA metalclad switchboard for the North Harrow Substation of the Eastern Electricity Board.

while a further 24 are now being made for the substation at West Weybridge.

METALCLAD SWITCHGEAR.

During the period under review, orders for metalclad switchgear covering the complete range have been well maintained, particularly for service overseas. For the Southern Region of British Railways, a further eight 33 kV, 750 MVA units are being supplied, following on the installation of over 300 units of this rating in connection with the frequency changeover in the London area. A recent contract placed by the Southern Electricity Board covers ten 33 kV, 750 MVA units for Woodmill Lane, while forty-nine 11 kV units rated at 250 MVA are in hand for Summer Lane substation of the Midland Electricity Board, to whom some 170 units have already been supplied. Of the overseas orders, mention may be made of the contract received to the order of His Highness the Ruler of Kuwait for 14 units rated at 33 kV, 750 MVA, in addition to 22 kV single-phase equipment for neutral earthing. Other overseas orders include twenty 6·6 kV, 250 MVA units, 9 of which are for the Australian Iron and Steel Co., Port Kembla and 11 for Bluff Power Station, Durban. For service in Punjab, forty-two 11 kV, 150 MVA units are being supplied.

Metalclad switchgear recently commissioned for the London Electricity Board substations includes twelve 22 kV, 500 MVA, and twenty-two 11 kV, 250 MVA units at Southwark Bridge Road, and eight 6·6 kV units rated at 500 MVA and 250 MVA for extensions at Lombard Road. Erection of the 33 kV switchgear at the North Harrow Substation of the Eastern Electricity Board is completed. This installation comprises 11 units rated at 750 MVA and is of interest in that the circuit breakers for the incoming supply have a current rating of 1,600 A which is unusually high for switchgear operating at 33 kV. Part of the switchboard is seen in fig. 20.

For the Pyrmont 'B' and White Bay Power Stations and the Homebush Switching Station of the Electricity Commission of New South Wales, eighty-seven 33 kV units have been supplied, four being rated at 1,500 MVA and the remainder at 1,000 MVA. Much of this switchgear has been in service for several years, the latest installation to be completed being that at the Homebush substation, fig. 21, where 22 units have recently been commissioned.

This substation controls the 33 kV systems by which the Sydney County Council distributes power over the inner and outer Metropolitan Areas. It is

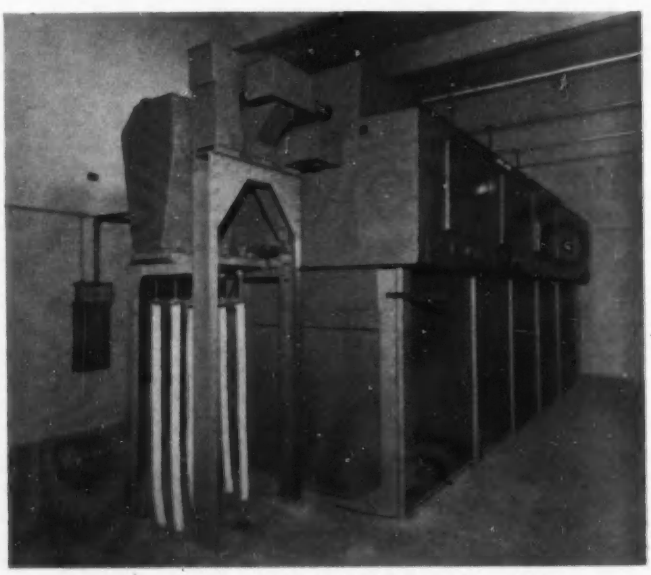


Fig. 21.—One section of the 33 kV, 1,000 MVA metalclad switchgear in the Homebush Switching Station of the Electricity Commission, New South Wales.

connected through 45 MVA transformers to the 132 kV power lines, the Northern, Western and Southern portions of the State's interconnected network being linked with the substation.

Multi-tier Airbreak Cubicle Switchgear.

When this class of gear was first introduced the main demand came from power stations for the control of auxiliaries. At that time it was expected that this form of switchgear would find a far wider field of service, and orders received from industry and large stores have proved this to be the case. Simple installation, ease with which extensions can be made, good appearance, small floor space, and safety in operation are factors which have led to the adoption of this switchgear in modern stores where the many electrical services required demand switchgear of a higher capacity than was needed in the past. Several installations have been executed for stores in the group controlled by Debenhams, Ltd., a typical board being shown in fig. 22. In each case the main incoming supply is controlled by an airbreak or oil circuit breaker, with fused-switches for the outgoing feeders. Changeover switches are provided to enable a supplementary supply to be brought into service for essential circuits in the event of failure of the main supply.

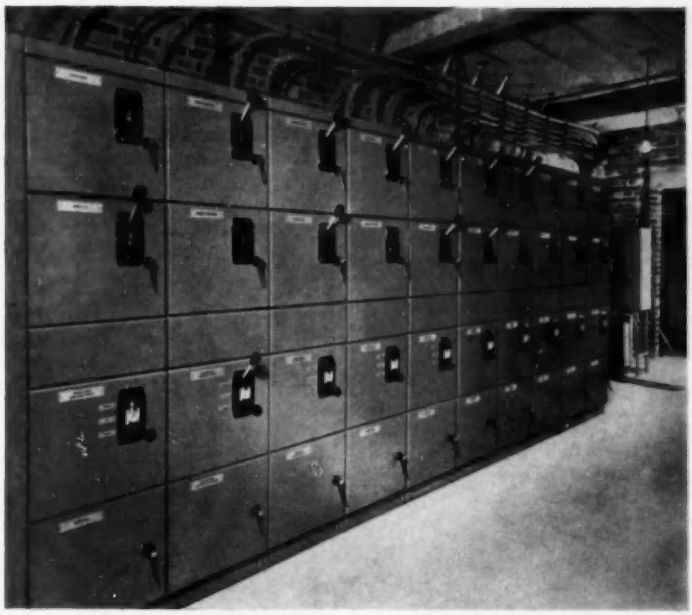


Fig. 22.—Airbreak cubicle switchboard at the store of Spooners Ltd., Plymouth.

PROTECTIVE SCHEMES AND RELAYS.

TYPE M RELAY.

When the type M relay was introduced, one of the advantages claimed was that it could be readily adapted for a wide variety of applications, several of which have already been described briefly (*G.E.C. Journal*, Vol. XXII, No. 1, pp. 11-12, January, 1955). Two recent additions to the range are described below.

ALTERNATOR FIELD FAILURE PROTECTION RELAY.

This relay, designated type MFF, has a D.C. wattmetric characteristic. It responds to all forms of field failure and is non-responsive to induced A.C. currents in the alternator field winding.

STATION BATTERY EARTH FAULT ALARM RELAY.

These relays, type MNB, are designed for applying to batteries of 110 and 240 volts and impose a negative bias on the D.C. system, the circuit diagram being shown in fig. 23. The circuit components are so proportioned that the following requirements are met :

(*a*) The relay responds to any faults on the D.C. system having a fault path resistance of less than 2,000 ohms.

(*b*) The whole D.C. system is at a negative potential with respect to earth so that corrosion troubles due to electrolytic action of the leakage current are eliminated.

(*c*) The maximum earth fault current which can flow is insufficient to cause maloperation of any trip relay.

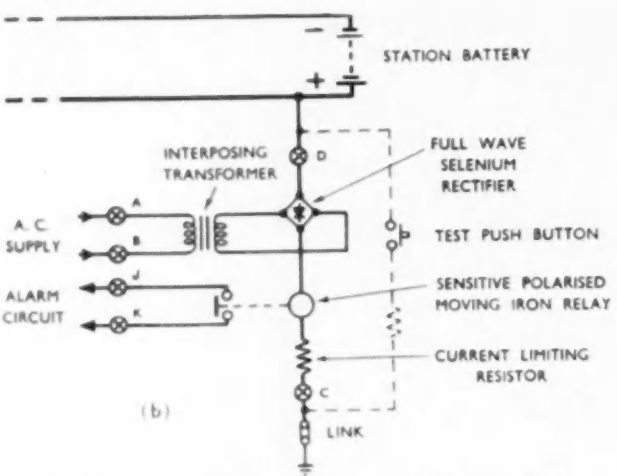


Fig. 23.—Circuit diagram of the battery earth fault relay, type MNB.

NEGATIVE PHASE SEQUENCE PROTECTION FOR ALTERNATORS.

A new negative phase sequence protection scheme, using a relay, type HNP, has been developed for safeguarding alternators against unbalanced loading. The new scheme is free from certain deficiencies which were inherent in earlier systems of protection.

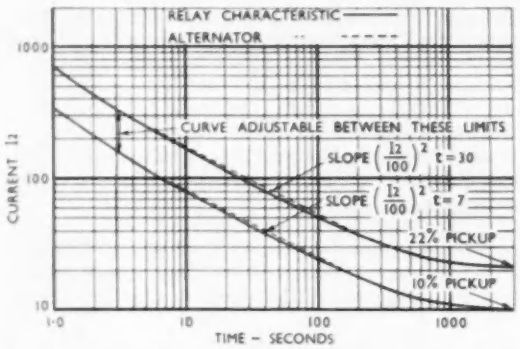


Fig. 24.—Characteristics of the negative phase sequence relay, type HNP.

The ability of an alternator to withstand unbalanced loading or negative phase sequence currents is usually expressed by the machine manufacturer by the following relationship :

$$\left(\frac{I_2}{100}\right)^2 t = k.$$

where

I_2 is the negative phase sequence current expressed as a percentage of the rated stator current,

t is the time in seconds,

k is a constant.

It will be seen from fig. 24 that the protective scheme closely matches the above characteristic and can be adjusted over a range of

$$\left(\frac{I_2}{100}\right)^2 t = 7{\cdot}0 \text{ to } \left(\frac{I_2}{100}\right)^2 = 30.$$

This covers all the known declared characteristics of alternators with solid rotors. The basic circuit is shown in fig. 25, and comprises a filter unit and relay which are energised from three line current transformers. The filter unit has an output directly proportional to the value of the primary negative phase sequence current, and produces a negligible amount of unwanted " spill " current under conditions of primary positive phase sequence currents, zero phase sequence currents and third harmonic currents. Furthermore, its operation is perfectly stable over the normal operating frequency range of power systems.

The relay comprises a small coil of resistance wire in which a thermocouple is embedded. The coil is heated by the filter output current, and by correctly proportioning its dimensions the time/current characteristic for a given temperature rise is made to match the ability of the alternator to withstand the flow of negative phase sequence currents. When the temperature of the heated coil reaches a predetermined level, a sensitive

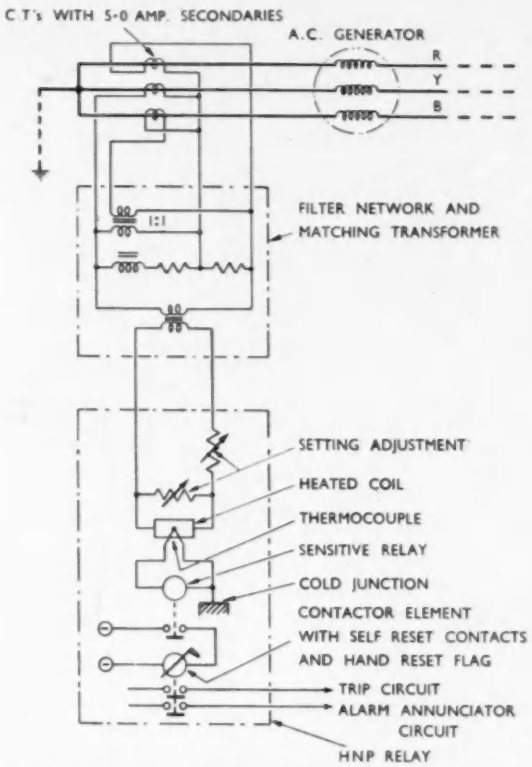


Fig. 25.—Basic circuit of the negative phase sequence relay, type HNP.

relay element operates and controls an auxiliary tripping contactor.

TRANSFORMER PROTECTION.

For use in a new method of high-speed differential protection of transformers, a relay, type PTB, has been produced. In addition to the load bias features of earlier schemes of this type, the new system incorporates a special harmonic biasing feature which ensures that the inrush of magnetising current associated with "switching-in" a transformer does not cause operation of the relay.

Differential and biasing characteristics are obtained by means of a static network which is supplied from current transformers, the output being fed to a robust relay of the attracted armature type. The salient performance features of the scheme are given below.

Fault setting. 12½ per cent. of the current transformer rated current.

Through-fault stability level. 15 times full load for standard equipments. Units to suit higher levels can be provided if required.

Bias features.

(*a*) Through-current adjustable from 20 to 40 per cent.

(*b*) Harmonic bias overcomes the effect of magnetising inrush currents.

Operating time. Less than 0·08 seconds with internal faults equivalent to five times the fault setting.

AUTO-RECLOSING EQUIPMENT FOR 132 kV SINGLE SWITCH STATION.

An equipment, which has been developed for delayed automatic reclosing of circuit breakers (dead-line charging) and fault throwing intertripping, has been successfully demonstrated to engineers of the Central Electricity Authority and Area Boards. It has been produced for controlling the 132 kV switching station at Daventry and further equipments are in hand. A single-line diagram is shown in fig. 26.

The function of the equipment is to restore power quickly to the supply point after any interruption. The method of operation is as follows.

After the clearance of a line fault it recloses the local 132 kV oil circuit breaker and the appropriate circuit breaker on the L.V. side of the transformer.

After the opening of the local circuit breaker on the occurrence of a transformer fault it first trips the remote 132 kV oil circuit breaker by closing the fault throwing switch. It then isolates the faulty transformer by opening the motor-operated isolator and finally recloses the 132 kV remote oil circuit breaker.

Important features of the equipment are: (1) it takes into consideration the switch positions before the fault; and (2) there is no risk of supplies which may be out of synchronism being connected together. Any synchronising must be done at the remote end of the 132 kV feeders. It operates also on the occurrence of simultaneous line and transformer faults. Should a fault persist after reclosure, the appropriate circuit breaker or breakers remain open.

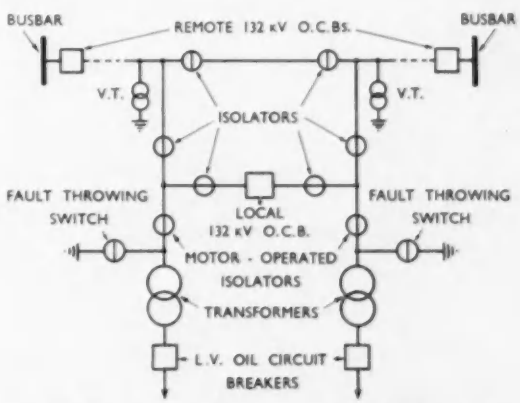


Fig. 26.—Single-line diagram of a single switch station.

Relays of robust design are used in the equipment, which offers considerable economic advantages over other methods of preserving continuity of supply at single switch stations and other grid supply points.

RECTIFIERS.

Although throughout the past twelve months considerable progress has been made in the development of power crystal rectifiers of the germanium and silicon junction types (see p. 73), the heavy demand for air-cooled mercury arc rectifiers is likely to be maintained for several years especially for traction service, printing press drives and for the electro-chemical industry. With this in mind plans for further extensions to the works have been prepared in order to increase manufacturing facilities and shorten delivery dates, while research and development work is being actively pursued on new types of multi-anode and single-anode mercury-arc rectifiers.

A notable feature of the orders placed is that over 50 per cent. are for service overseas, and include equipments for Portugal, Holland, Greece, Egypt, India, Canada, Australia and New Zealand.

Although only of small output, the complete transportable substation equipment (fig. 28) supplied to the Kuwait Oil Company is of interest. The rectifier is rated at 60 kW, 110 V. and, together with the transformer and switchgear, is mounted on a chassis and enclosed in a sheet steel kiosk. The equipment is designed to operate under severe atmospheric conditions, including dust storms and temperatures up to 80 deg. C. A single fan draws air through filters into the transformer compartment, whence it passes into the rectifier cubicle and, after passing over the rectifier cylinder, is discharged through fine gauze vents at roof level.

In the home market twenty of the forty-nine 2,500 kW equipments for the Southern Region of British Railways are in service, and their performance under severe loading conditions accompanied by considerable variations in ambient temperature has given complete satisfaction. During the year official tests have been witnessed at the Works by officials of the railway, when two of the four rectifiers normally associated with the main transformer were subjected to the heavy-duty load cycle specified by the customer.

Fig. 28.—A 60 kW 110 volt transportable rectifier substation for the Kuwait Oil Company.

In this test, the rectifiers, operating 12-phase, were subjected to a series of peak loads reaching 6,750 A at four-minute intervals for two hours, followed by a three-hour run at full load. The oscillogram is shown in fig. 27, and the performance of the rectifiers fully substantiated the claims made for their sound design and construction.

A new single-anode rectifier (fig. 29) of improved design and performance has been developed, and created considerable interest at the International Printing Machinery and Allied Trades' Exhibition at Olympia in July, where a three-phase, full-wave group of rectifiers was shown in operation by Witton-James, Ltd., as part of that company's rotary press drive.

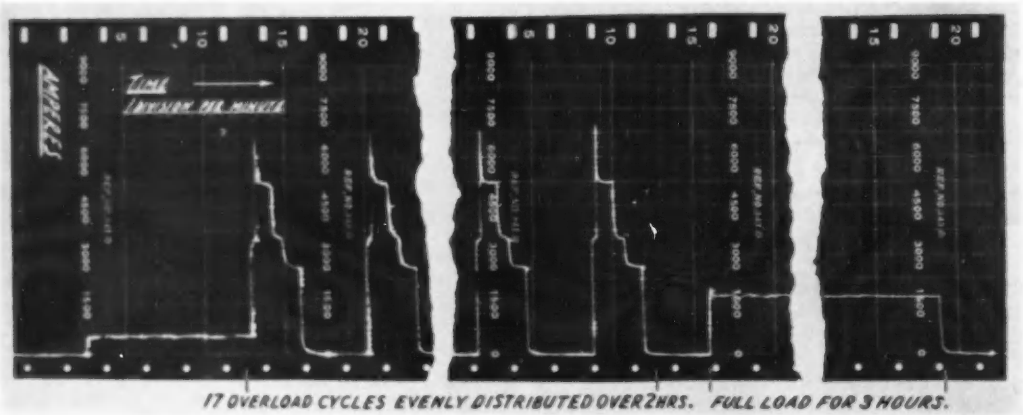


Fig. 27.—Oscillogram of the official test on 2,500 kW rectifier equipment for the Southern Region of British Railways.

Fig. 29.—A new design of single-anode rectifier for rotary printing press and similar drives.

Fig. 30a.—60° impulse waves.

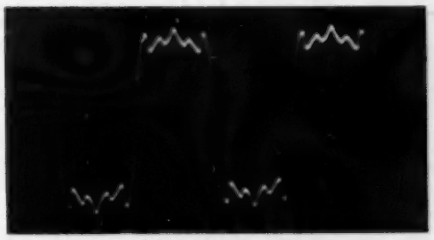


Fig. 30b.—180° impulse wave.

GRID CONTROL.

The static grid control circuit described previously in this Journal,* has been redesigned to incorporate a new technique. The separate negative bias arrangements, which are essential when using a peaky or short-duration positive pulse, have been eliminated, thus reducing the danger of overloads caused by possible failure of this auxiliary supply. The 60° pulse (fig. 30a) from the grid pulse transformer has been extended to 180° (fig. 30b); the negative half-cycle in consequence is also 180°. The negative half-cycle is sufficient to bias the grids and prevent the rectifier anodes conducting until the pulse becomes positive. This development also simplifies the application of arc suppression to equipments where variation of the D.C. voltage is by grid control.

* *G.E.C. Journal*, Vol. XIX, No. 4, pp. 229-238, October, 1952.

Mechanical Engineering

MINERAL DRESSING.

Development work on mineral dressing over the past twelve months has largely been concerned with heavy medium separation which is frequently carried out in a conical vessel containing the heavy medium. The density of the medium is adjusted so that it falls between that of the heavier and lighter minerals. The drawback with the usual conical heavy medium separation vessel is that the heavier 'sink' material is withdrawn through an air lift pipe, and design and economic factors prohibit the removal of pieces larger than about 2½ in. by this method.

As it may be necessary to treat pieces possibly as large as 9 in., a new type of separation vessel is being developed. A laboratory size unit has been made by Fraser & Chalmers (fig. 31.) and will be exhaustively tested in the Mineral Dressing section of the Research Laboratories. In operation the ' sink ' material is withdrawn from the bottom of a cone by means of a rotary elevator rather similar to a water-wheel. The cone base is open with its edge welded to the rotor casing, and medium and ' sinks ' material can enter the rotor casing where the slowly revolving rotor carries both upwards and drops them from a hole in the top of the casing on to the ' sinks ' chute. The material which floats is discharged in the normal way over a weir cut in the cone rim.

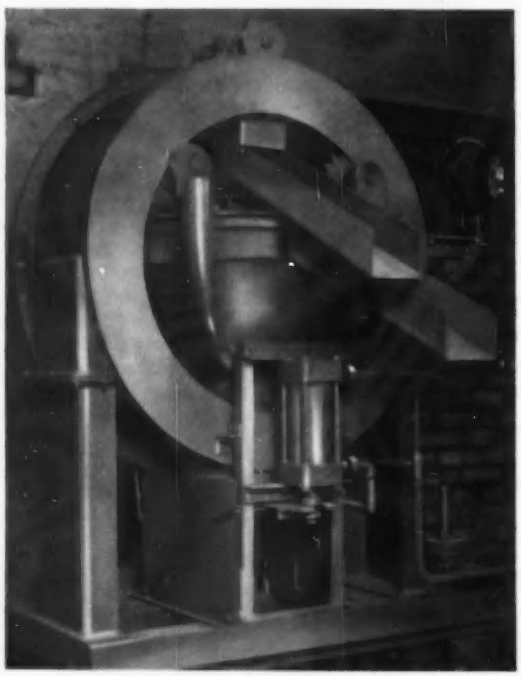


Fig. 31.—A laboratory size mineral dressing unit.

It is envisaged that commercial units will have a cone some 8 ft. in diameter with a rotor casing about 12 ft. in diameter overall. The motor drives will incorporate hydraulic couplings to provide immediate overload protection. The capacity for the commercial unit is conservatively rated at 60 tons per hour pending proving trials.

An O.E.E.C. mission recently visited mineral dressing plants and research establishments in various European countries and a similar mission visited the U.S.A. in 1951. The object was to study the mineral dressing industry and to examine facilities available for research in connection with low grade ores.

Among the recently published findings* of the European mission is the statement ' A great deal of further research, both fundamental and applied, is required in the field of electrostatic separation.'

This subject has, in fact, been studied at the Research Laboratories during the last two years, and a commercial high voltage separator has now reached the drawing board stage. Some fundamental work is being continued. The original laboratory size machine in the Mineral Dressing section is seen in fig. 32 and the charging electrode in fig. 33.

The commercial machine will be of the earthed roller type and the final design will probably incorporate an improved charging electrode.

A variety of minerals can be separated in the machine with a high feed rate and very low power consumption, the basis of separation being surface conductivity. Particle size range will depend to some extent on the materials being separated but 1·0 mm is roughly the upper limit, while any significant quantity of minus 200 mesh material will cause a serious reduction of capacity.

Research has revealed much of the mechanism of separation, and correct adjustment of the variables of the machine to suit any separation problem should be a simple procedure.

A full-size machine will be installed at the Laboratories in due course for routine testing of ores and other materials.

An order is being executed for The Silvermines Lead & Zinc Co. Ltd., of Eire, for a 30 tons per hour heavy media separation plant. This plant will treat mined lead-barytes ore in order to eliminate gangue before treatment in the existing flotation plant. In this way the flotation plant will be able to produce about double the tonnage of final concentrates without any extension.

A 7 ft. separatory cone will be employed, using ferro silicon medium. The cone is of a new design incorporating a scoop-controlled fluid coupling drive to allow low starting torque without frequent use of the

*"The Mining and Dressing of Low-Grade Ores in Europe". *Technical Assistance Mission*, No. 127. O.E.E.C., 2 Rue André-Pascal, Paris, 16.

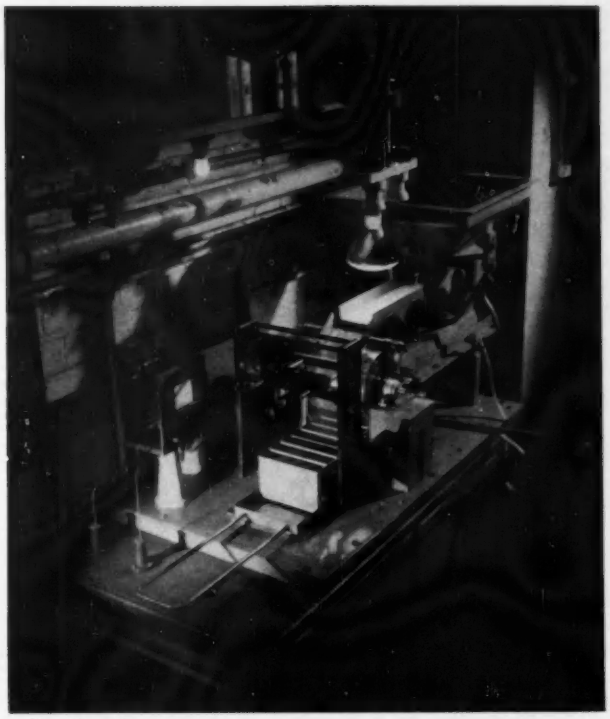


Fig. 32.—The original electrostatic separation unit at the Research Laboratories.

motor starter. To assist further in starting up the cone after the medium has settled out into a very dense sludge, the agitator is built entirely of steel tubes. These tubes are airtight and are fitted with several special axial flow stainless steel non-return valves. By connecting a quick-release air hose to the top of the agitator while at rest, very effective " boiling-up " of the medium into normal suspension should be possible. This process can be lengthy on plants which shut down over the week-end, especially where ferro silicon medium is employed.

The plant employs the standard heavy media separation flowsheet including a 12 ft. thickener, 24 in. densifier, and two 24 in. magnetic separators. The building steelwork is being made in Dublin to Fraser & Chalmers drawings.

All motors and starters are of G.E.C. manufacture. The plant is scheduled for completion in March, 1957, and erection and starting up will be carried out by Fraser & Chalmers.

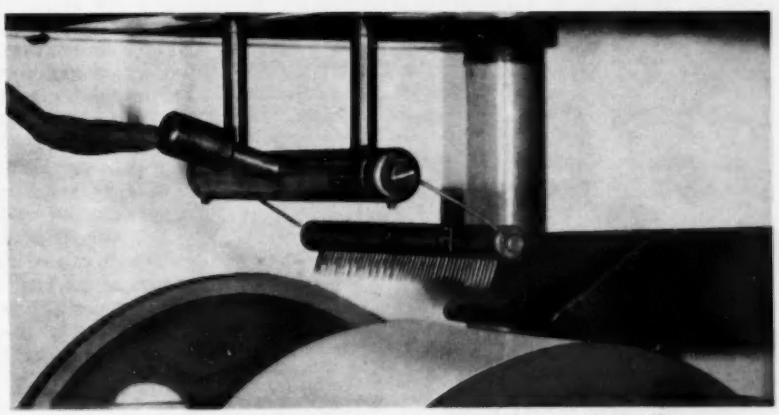


Fig. 33.—Electrostatic head of the separation unit illustrated in fig. 32.

PENNSYLVANIA PLANT.

An order has been received recently from the Appleby-Frodingham Steel Co. Ltd. for a seventh Dixie moving breaker plate hammer mill, following the very satisfactory results obtained from the six Dixie mills of this type recently put to work at the company's new ore crushing plant (fig. 34).

So successful has been the performance of these machines installed at Appleby-Frodingham that extensive enquiries have been received for further steelworks projects.

An interesting further development in this connection is the receipt of an enquiry from the firm of Lurgi, of Frankfurt-on-Main, Germany, for four similar machines in connection with steelworks in which that company is interested.

Several orders have been received for roller-mounted Bradford breakers for the National Coal Board in connection with the mechanisation of collieries. These orders follow the supply and installation of three large roller-mounted Bradford breakers for Barnburgh and Manvers Main Collieries, and also a spider-mounted machine for treating middlings, in addition to a roller-mounted Bradford breaker supplied for New Stubbin Colliery.

Present orders cover two machines for Cadeby and Silverwood Collieries for No. 3 area, North-Eastern Division, and a large roller-mounted machine for the Rising Sun Colliery, Northern (N. & C.) Division.

In addition to the above, there are in hand three roller-mounted Bradford breakers for collieries in Belgium, following the successful installation of two roller-mounted machines for the Houillères du Bassin du Nord et du Pas-de-Calais at Douai.

Three Bradford breakers have been supplied in connection with coking plants for gas works ; note-

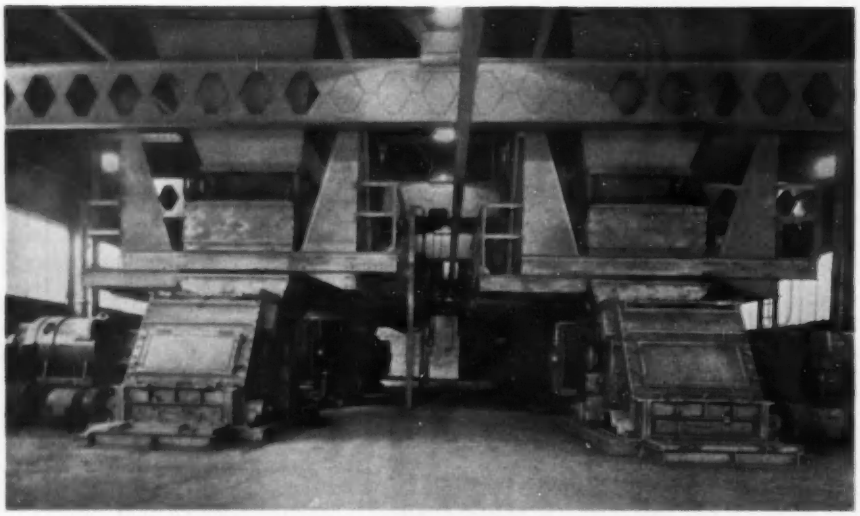


Fig. 34.—Six Pennsylvania Dixie mills at the Appleby-Frodingham Steel Co. Ltd.

worthy among them is a large spider-mounted machine for the North Thames Gas Board at Beckton Gas Works, where a Bradford breaker has been in use since 1930.

DUST PRECIPITATION PLANTS.

During the period under review, dust collection and precipitation plants have been put into operation at The Steel Company of Wales, where coke dust from the coke screening plant is being handled; at Spillers Ltd. where flour dust is dealt with; at Harrison & Son (Hanley) Ltd. where dust produced during the fine grinding of a number of solids used in the pottery trade is taken care of; and at the Crown Fuel Works of the National Coal Board, where coal dust from a coal drying plant is precipitated and passed to the briquetting plant for use.

In each case the plant comprises covers and hoods at the points where the dust is produced, with steel ducting connecting the hoods to the micron precipitators. The equipment is capable of precipitating particles of dust down to five microns and less in mean diameter. The dust-laden gases are drawn through the plant by means of suction fans, which are usually placed on the " clean gas " side of the plant.

WINDING ENGINES.

The National Coal Board's programme for modernising the collieries has resulted in an important increase in orders placed both for A.C. and D.C. winders and several installations have been commissioned within the past twelve months. Of these the A.C. winders at Chislet Colliery, Kent (fig. 35) and Cwm Colliery, South Wales (fig. 37), are of particular interest in that they incorporate the system of speed control which formed the subject of an article in an earlier edition of this journal.* It will be recalled that the first winder in Great Britain to use this method of control was commissioned at Avon Colliery, South Wales, some eighteen months ago, and its subsequent performance has given complete satisfaction.

At the Chislet Colliery, the cage winder at the North Pit has been converted from steam to electric drive. The steam winder (fig. 36), a cross-compound engine, was installed by Fraser & Chalmers in 1914. The output is five tons of coal or eight tons of stone per wind from a depth of 1,380 ft., the latter being over limited periods of one-and-a-half hours at infrequent intervals. The slipring driving motor of the new winder is rated at 1,200 h.p., 3·3 kV, 365 r.p.m., the speed control being substantially the same as that provided for the Avon winder. When dynamic braking is applied the motor will give a continuous braking torque of 70 per cent. full-load torque or 150 per cent. full-load torque for one minute. A duplicate equipment is in hand for this colliery and will be brought into service next year.

For Cwm Colliery, an automatic skip winder (fig. 37) has been installed to raise twelve tons of coal per wind from a depth of 2,253 ft., provision being made for occasional man-riding. This winder is driven through gearing by a 3,000 h.p., 11 kV, 317 r.p.m. slipring motor arranged for speed control.

The system of control is a development of that referred to above, and provides for push button or fully automatic working in addition to manual operation. When operating on push button control, winding is initiated by the on-setter and the banksman; thereafter acceleration, deceleration and decking proceed automatically. For fully automatic winding the plant

* *G.E.C. Journal*, Vol. XX, No. 3, pp. 161-167, July, 1953.

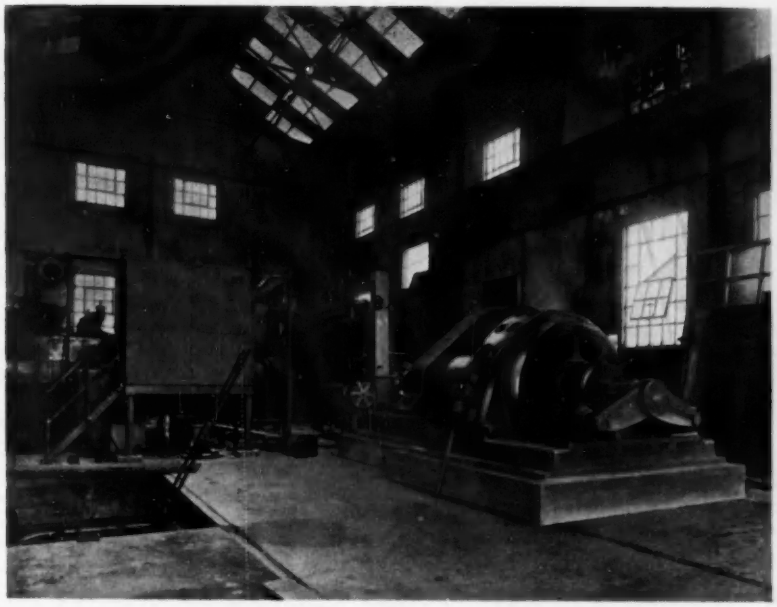


Fig. 35.—1,200 h.p. A.C. winder at Chislet Colliery.

begins to operate as soon as the bottom skip is fully loaded, charging and discharging of the skips proceeding automatically so long as coal is available for winding. Other features of interest provided by this installation are that it is one of the first winders in this country to operate at 11 kV, and that the liquid controller is one of the largest to be built, capable of a dissipation of 1,500 h.p. The 11 kV, 300 amp stator reverser for this winder is arranged for pneumatic operation and was briefly described in an earlier review of Progress.* When on test, the contactors successfully interrupted a current of 900 amp, and the equipment satisfactorily withstood the normal flash test at 28·5 kV, and an impulse test of 70 kV.

Also deserving of mention are the 3,700 h.p. geared D.C. double-drum winders now being commissioned at the Silverwood East and Cadeby Main Collieries in the North Eastern Division of the National Coal Board. The drums are 18 ft. dia. by 5 ft. wide and each winder is designed to raise twelve tons of coal per wind from a depth of 2,299 ft., giving an hourly output of 525 tons. The winder motor is supplied from a 2,650 kW Ward Leonard set driven by an 11 kV synchronous motor.

A feature of considerable interest is the adoption of control exciters to ensure speed of response with high stability. The control exciters provide excitation for the field of the Ward Leonard generator and afford an overriding torque limit control.

For the Cadeby Main Colliery an order has now been placed for a 2,250 h.p. double-drum A.C. service winder for No. 1 shaft. The drums are 16 ft. dia. by 4 ft. wide, the winder being designed for a cage load of 4·34 tons per wind, giving an hourly output of 160

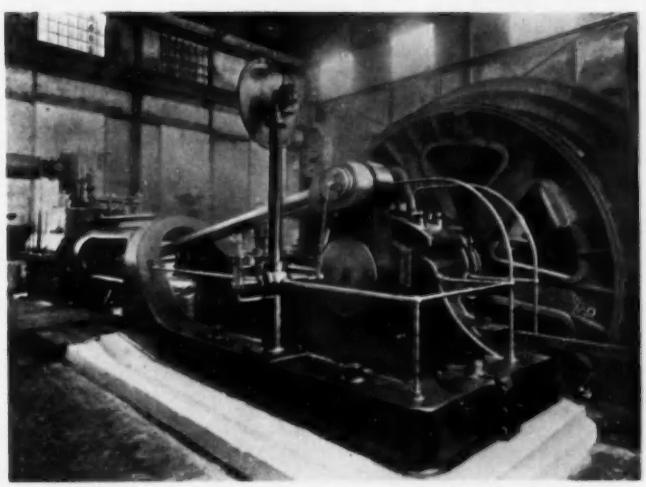


Fig. 36.—The cross-compound steam winder installed at Chislet Colliery in 1914, now replaced by the motor drive illustrated above.

* *G.E.C. Journal*, Vol. XXI, No. 1, pp. 20-21, January, 1954.

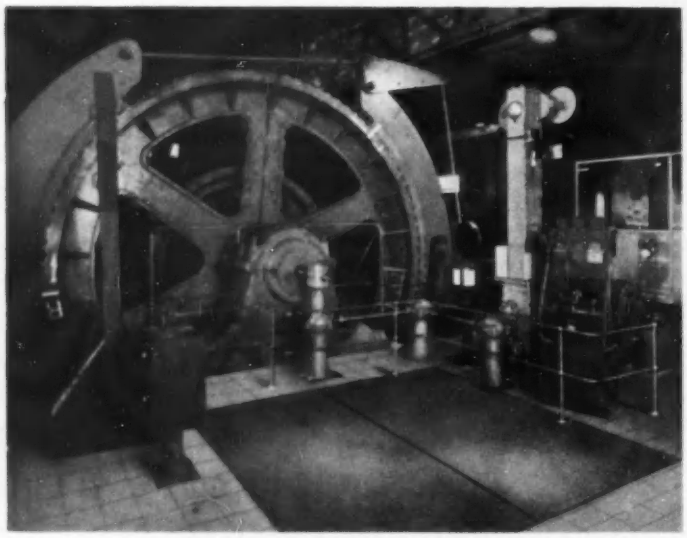


Fig. 37.—3,000 h.p. automatic A.C. skip winder at Cwm Colliery.

tons when raising stone from a depth of 2,280 ft. The system of control will incorporate full dynamic braking and speed control.

Also on order for the National Coal Board is a fully automatic 4-rope friction winder for the Seafield Colliery in the Scottish Division. The winder will serve No. 1 shaft and will raise fifteen tons of coal per wind in skips from a depth of 1,930 ft. giving an output of 615 tons per hour. The 10 ft. dia. friction drum will have a speed of 59·45 r.p.m. and carry four 1¼ in. diameter locked-coil ropes. It will be driven through gearing by two D.C. motors each rated at 1,350 h.p. and arranged for Ward Leonard control in conjunction with control exciters.

Overseas contracts include winding equipment for the Mount Isa Mines Ltd. and Cessnock Collieries Ltd., Australia, and the Messina Development Co. Ltd., South Africa. For the Mount Isa Mines a double-drum winder driven through gearing by two 2,250 h.p. D.C. motors is being supplied. The equipment will be capable of raising twelve tons of ore per wind from a depth of 4,000 ft., giving an hourly output of 350 tons. Automatic push button control from twelve different levels will be provided and the control scheme will incorporate control exciters operating in conjunction with a 3,350 h.p. Ward Leonard-Ilgner set.

The order for Cessnock Collieries Ltd. covers a single-drum winder designed for an output of 248 tons per hour when winding from a depth of 1,227 ft. The D.C. driving motor is rated at 1,450 h.p., 54 r.p.m., and will be directly coupled to the winder. Here again, the Ward Leonard system of control incorporating control exciters will be used. It is of interest to note that most of the mechanical parts for this winder will be manufactured in Australia from design data supplied from the Erith Works. For the Messina Development Co. Ltd., an 830 h.p. D.C. winder with Ward Leonard-Ilgner set is being supplied.

Both the National Coal Board and overseas mining companies continue to show much interest in friction winders, with a trend towards the multi-rope type. A further Koepe (single-rope) friction winder has been put into service at Bold in the North West Division. The mechanical parts of this winder were made at Erith Works. The installation, together with the

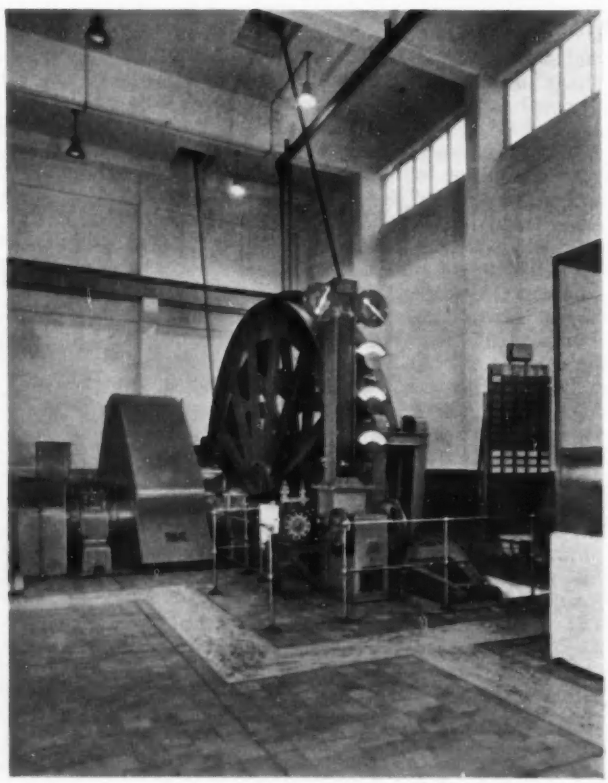


Fig. 38.—Koepe winder at Bold Colliery.

two-drum winders, the mechanical parts of which were also made at Erith, forms part of the extensive modernisation plans at the colliery.

Bold Koepe winder (fig. 38) is believed the largest installation of its kind working in Great Britain to-day. The fabricated wheel is 26 ft. dia. at the rope tread. Arms of heavy rolled steel channel section are welded to a cast steel boss ; the outer ends of the arms are welded to the rim which also carries two brake paths of high carbon manganese steel. The welded structure is normalised to relieve stresses before final machining. The main bearing journals are 22 in. dia. by 33 in. long and the winder is driven through single-reduction double helical gears.

The principle of friction winders has been dealt with in an earlier issue of this journal (Vol. XVII, No. 2, pp. 59-88, April, 1950) and this machine is designed to include the latest developments.

For the President Brand Mines in South Africa, the mechanical parts of a single-drum winder 10 ft. by 5 ft. 9 in. are to be supplied. The winder will be designed at Erith, and the mechanical parts, with the exception of the shaft and reduction gears, made in South Africa.

Mechanical parts for two double-drum winders are also on order; these are for Murton Eppleton Colliery, Hawthorn Pit, in the Durham Division of the National Coal Board, and have drums 16 ft. in diameter by 10 ft. wide.

Flameproof Push, Lamp and Switch Unit.

Designed on similar lines to the " Litealarm " described in the *G.E.C. Journal* for February, 1955, p. 20, a flameproof push, lamp and switch unit (fig. 39) has been introduced which has numerous applications either in conjunction with Litealarm systems, or as an independent remote control unit with back indication. When used in a Litealarm installation, the unit provides a flameproof lamp indication repeating the Litealarm itself, and with the facility of initiating or cancelling an alarm.

The switching also enables two separate circuits to be controlled, such as the " close " and " trip " coils of a circuit breaker or the operating circuits of a contactor. In these circumstances they

Fig. 39.—Flameproof push, lamp and switch unit.

can be arranged either to indicate the running condition or to serve as a " supply on " indication. An electro-mechanical interlock circuit can be provided to ensure that two deliberate switch movements must be made before the circuit controlled is affected, so that there is a safeguard against random or accidental operation, and the same facility can be used also to sound an alarm before the circuit concerned is closed or opened. Provision can be made for latching the switch in either or both of its positions to suit other circuits. The unit is available for 250 V, 110 V or 24 V circuits and the handling capacity of the switches on A.C. circuits is either 5 amp at 250 V or 10 amp at 125 V.

Coal Preparation Plant

Throughout the year intensive development on coal preparation plant has followed two major courses. The first of these has been followed at the Research Laboratories, where experiments with froth flotation cells have been continued. The object of this research has been to improve separation results obtained from flotation cells by testing a number of reagents and froth producers, and to improve the settling rates of fines in suspension; also to increase the output from individual cells without increasing the running costs.

When the results of these experiments are consolidated it should be possible to provide froth flotation cells which will competently treat fine coal at a faster rate than heretofore, the upper particle size limit being higher than usual for this process. Greater use can thus be made of coal resources.

The other major sphere in which much research has taken place during the period under review has been that of middlings extraction from the Chance cone (fig. 40). On a three-product cone (clean coal, middlings and refuse) it is necessary to secure an accurate "cut" in order that the ash content of the three products may be within very close limits. Experiments have been carried out with the positioning of the middlings take-off column both radially and tangentially round the cone in order to secure further data. The object is to ensure that the percentage of combustible coal in the refuse is reduced to the absolute minimum, that the "cut" through the cone for middlings produces a product of a reasonably balanced ash content, so that this coal may be sold economically to consumers possessing boilers which can be fired by low grade coal; and that the theoretical ash content of the clean coal remains within design limits.

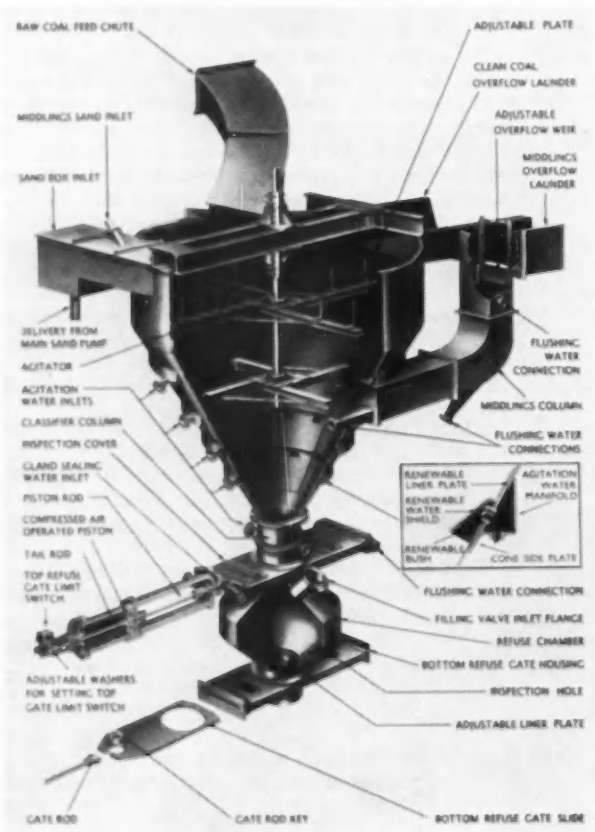


Fig. 40.—Sectional arrangement of the Chance cone.

The contract is a comprehensive one in that, in addition to the coal preparation plant, a dust collecting plant, tippler house extension, civil engineering work, electrical equipment and wiring also form a G.E.C. contract. Forty-seven electric motors of various horsepowers are included and the lighting of the plant is by means of 100 watt Osram tungsten lamps in angle type and dispersive reflectors; 250 watt mercury lamps with reflectors illuminate the picking belt.

The first coal washing plant to be commissioned in Australia, at Corrimal, has been installed by the Corrimal Colliery, which is on the Southern Coalfield of New South Wales (fig. 41). It has a capacity of 200 tons per hour. This plant is a further instance of the adaptability of the Chance process, for here again the cone has been fitted with a take-off for a middlings product which will be added at a later date if required.

The coal treated in the plant is renowned for its coking qualities as it is won from the No. 1 Bulli Seam, and the colliery supplies

The washery at Horden Colliery has been commissioned during the year under review. This plant, with a capacity of 210 tons per hour input of plus 1½ in. R.O.M. coal, includes a 10 ft. diameter Chance cone which is fed from the raw coal screen. The raw coal screen is fitted with perforated plates to extract up to 170 tons per hour of 8 in. × 1½ in. raw coal, this being fed to the cone. The oversize is hand-picked.

coal for coking for a wide range of secondary industries in Australia, and sends substantial quantities overseas.

Progress at Cwm Colliery (fig. 42) has been marked during the year and in addition to the coal preparation plant, a 3,000 h.p. electric winder has been installed (p. 24) and steam turbo-generators are being supplied.

Among orders received has been that for a plant at the Hawthorn Pit in the Durham Division of the National Coal Board which will be designed for a throughput of 750 tons of coking coal per hour. The arrangement of internal conveyors permits the re-treatment of the fines during the back-filling shift.

A further order for a plant at Desford in the East Midlands Division has been received.

Fig. 41.—Chance coal washing plant at Corrimal, New South Wales.

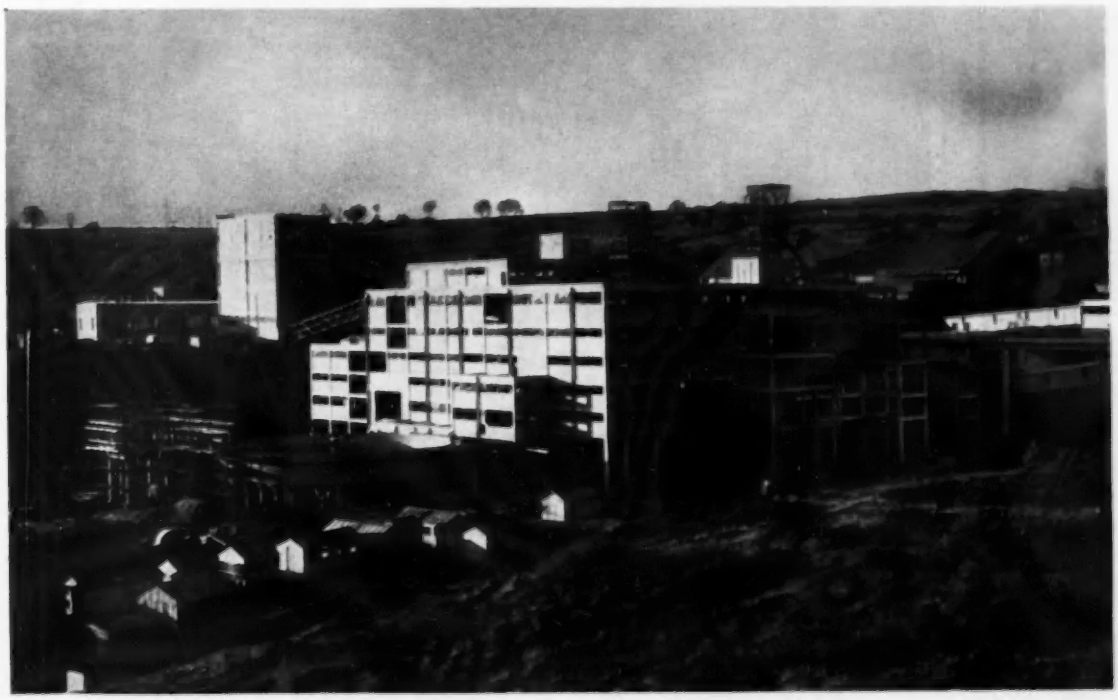


Fig. 42.—The washery under construction at Cwm, near Pontypridd.

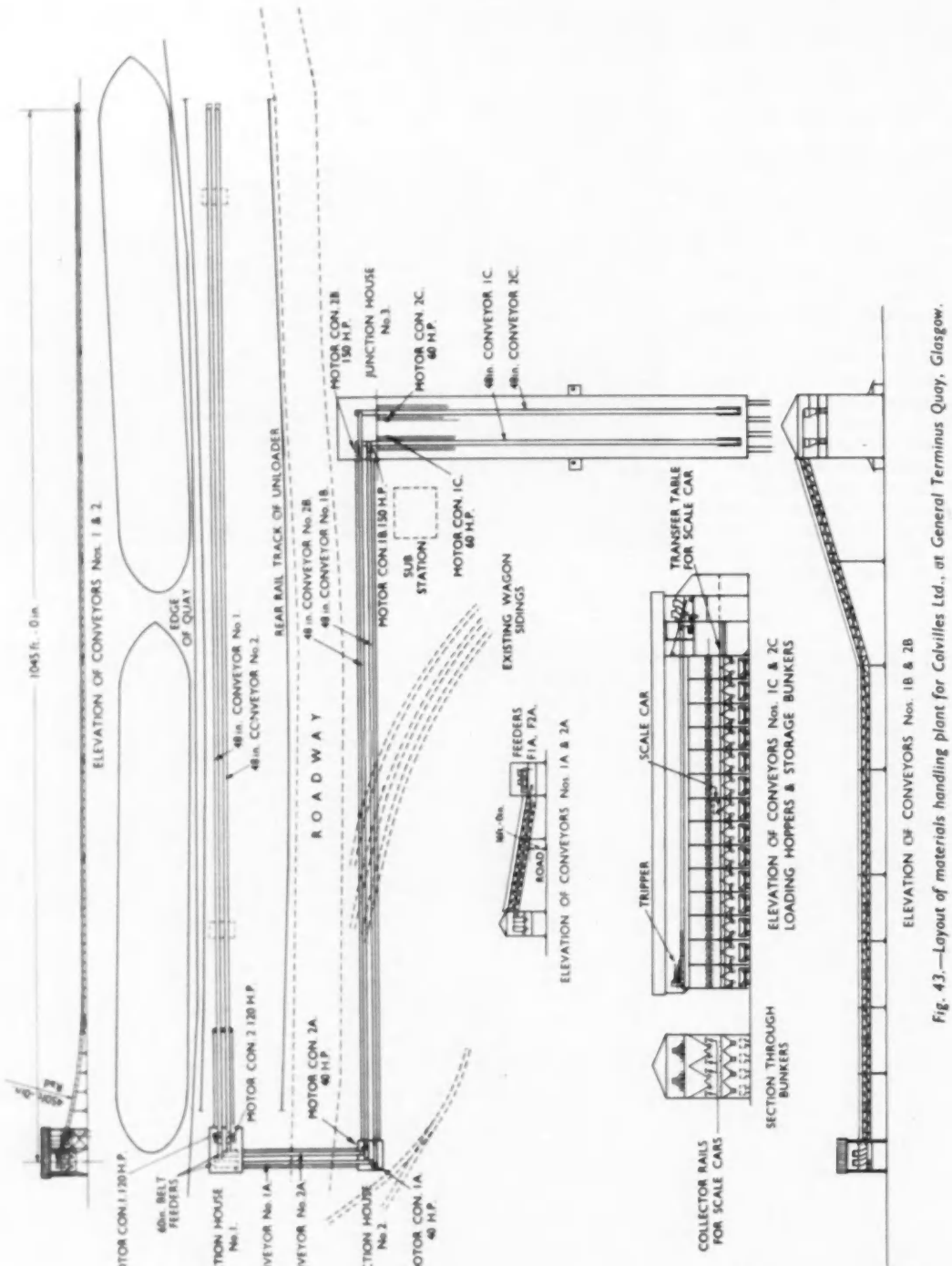

1045 ft. 0 in.
ELEVATION OF CONVEYORS Nos. 1 & 2
EDGE OF QUAY
REAR RAIL TRACK OF UNLOADER
48 in. CONVEYOR No. 1
48 in. CONVEYOR No. 2
48 in. CONVEYOR No. 2B
48 in. CONVEYOR No. 1B
ROADWAY
MOTOR CON. 2B 150 H.P.
JUNCTION HOUSE No. 3.
MOTOR CON. 2C. 60 H.P.
48 in. CONVEYOR 1C.
48 in. CONVEYOR 2C.
MOTOR CON. 1B 150 H.P.
SUB STATION
MOTOR CON. 1C. 60 H.P.
TRANSFER TABLE FOR SCALE CAR
EXISTING WAGON SIDINGS
FEEDERS F1A. F2A.
ROAD
ELEVATION OF CONVEYORS Nos. 1A & 2A
SCALE CAR
TRIPPER
ELEVATION OF CONVEYORS Nos. 1C & 2C LOADING HOPPERS & STORAGE BUNKERS
SECTION THROUGH BUNKERS
COLLECTOR RAILS FOR SCALE CARS
ELEVATION OF CONVEYORS Nos. 1B & 2B
MOTOR CON 1 120 H.P.
60 in. BELT FEEDERS
JUNCTION HOUSE No. 1.
48 in. CONVEYOR No. 1A
48 in. CONVEYOR No. 2A
MOTOR CON 2 120 H.P.
MOTOR CON 2A. 60 H.P.
JUNCTION HOUSE No. 2
MOTOR CON 1A 60 H.P.

Fig. 43.—Layout of materials handling plant for Colvilles Ltd., at General Terminus Quay, Glasgow.

Materials Handling Equipment

In dealing with progress twelve months ago reference was made to a 500 tons per hour ore handling and screening plant in course of manufacture for Colvilles Limited for installation at the Clyde Iron Works. Since then another contract has been received from this important steelmaker for its General Terminus Quay installation, which is an essential link in the supply of iron ore to Colvilles new Ravenscraig works at Motherwell as well as to the present Clyde Iron Works.

The site of the plant (fig. 43) is on the bank of the Clyde in the Glasgow dock area, where ore-carrying ships will discharge direct on to conveyors, delivering to overhead bunkers of some 14,000 tons capacity. Scale cars running beneath these bins will transfer weighed amounts of ore to a series of smaller bunkers immediately below the main storage bunkers. The purpose of this is to enable a complete train of ore wagons, each of 35 tons capacity, to be loaded in one operation and to maintain the essential supply of ore to the ironworks while keeping the considerable amount of traffic within the capacity of the rail link between the docks and ironworks.

Advantages to be gained from the blending of iron ore are becoming widely appreciated, and a contract has been received from Ilva Alti Forni E Acciaierie D'Italia of Genoa, the largest producer of steel in Italy, for an ore blending and reclaiming plant which will be the first installation of its kind in that country. The plant is designed to feed ore into four blending piles, each of a capacity of 11,900 metric tons, at the rate of 400 tons per hour. An ore reclaiming machine spanning the width of the ore bed reclaims blended ore by means of an oscillating harrow at the front of the machine, and a plough type conveyor feeding on to conveyor strands running the length of the beds.

Fig. 44.—A battery of single-deck Gyrex screens in the primary crusher house at the Appleby-Frodingham Steel Co.

Coal washing plants which the Company's Coal Preparation Department is supplying to the National Coal Board involve a large amount of conveying equipment and requirements for these plants continue on a considerable scale.

Gyrex screens (fig. 44) continue in popular demand and the 1955 production included a single order for twenty screens of this type from the Anglo-American Corporation of South Africa.

Other industrial plants on order include three loading mechanisms for tunnelling operations to be undertaken for British Railways in the London area

by Chas. Brand & Son Ltd. These loaders will be dragged forward by the digging shield to receive the spoil, which they will convey to a loading hopper whence it will be taken from the tunnel by narrow-gauge trucks. This equipment will also be used for handling the concrete lining sections of the tunnels.

Development work continues on a number of items ; the field tests on the new 5 in. range of idlers (fig. 45) have been successful and it is anticipated that production will begin this year.

The Robins-Messiter reclaiming machine has been redesigned and simplified. The cost of the machine has consequently been reduced and the new arrangement permits the foundation cost also to be considerably less. All this has been achieved without sacrifice of blending efficiency.

Designs have been completed for a new wagon marshalling system whereby manpower is cut down on tippler installations. With this system the sequence of operations after the loaded train has been brought to the " full " sidings requires one only operator for the tippler and wagon movement until all wagons are discharged and placed in the " empty " sidings. This wagon marshalling system is able to handle all types of mineral wagons in service, including the latest type of continuous brake fitted and hoppered rolling stock.

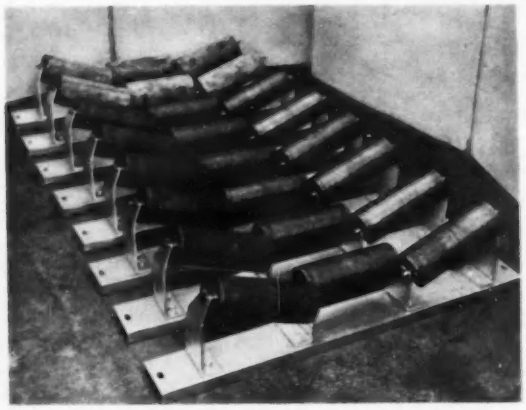


Fig. 45.—5 in. idlers from the new range prepared for field test.

Other designs recently completed include a new vibratory screen, the prototype of which is in course of manufacture.

Rolling Mills

Fig. 46.—The 74 in. by $\frac{3}{8}$ in. cold cut-up line at Margam Works of the Steel Company of Wales viewed from the entry end.

At the Margam Works of the Steel Company of Wales, the 74 in. by $\frac{3}{8}$ in. cold cut-up line is now in full production. It is the first of its type to be commissioned in this country and is designed to cut strip from 20-ton coils automatically into lengths varying from 4 ft. to 36 ft. and to pile the cut lengths. The maximum speed of operation when cutting $\frac{3}{8}$ in. metal is 150 ft. per min., rising to 250 ft. for $\frac{5}{16}$ in. strip. For this installation all the electrical equipment was designed and manufactured at the Witton Works and includes a 5-machine motor generator set, nine force-ventilated D.C. motors totalling over 700 h.p., and all the associated control gear. Rapid speed response combined with stability is assured by the use of control exciters for the motor generator set and for current control of the mandrel drive. A general view of the line is shown in fig. 46 and the up-cut shear in fig. 47. The control desks incorporate the new design of console type switch to which reference was made in last year's progress review. With this design of switch a particularly compact desk can be built, all switches being within comfortable reach of the operator when seated.

A recent contract placed by the Steel Company of Wales covers all the electrical equipment for two continuous electrolytic tinning lines to be installed at its Velindre Works. These lines will be capable of running at any speed from 250 ft. per min. up to a maximum of 1,250 ft. per min. For each line, the electrical equipment includes a 510 h.p. main Ward Leonard set, three auxiliary motor generators comprising exciters, boosters and the high-frequency control alternators, some 50 motors, and all associated switchgear.

Very precise relative speed control of the motors along the line and accurate tension control are essential features of the installation. The Ward Leonard set, operating in conjunction with electronic and magnetic amplifiers, provides the main speed control, while 50-cycle magnetic amplifiers are used in the control of the coiler and uncoiler. For maintaining constant tension, 400-cycle magnetic amplifiers operate in conjunction with tension control boosters. Loop control of the strip between the entry and processing sections of the line is achieved by means of photo-electric equipment. All the electronic and magnetic amplifiers are accommodated in the main contactor board, which is about 90 ft. long.

In connection with the conversion of an existing 5-stand finishing mill to a 7-stand mill at the Hawarden

Bridge Steelworks of John Summers & Sons Ltd., a large amount of electrical equipment is involved, including D.C. motors for the main drives of three of the stands, a 10,000 kW grid-controlled rectifier equipment and all the associated control gear. Each of the stand motors is rated at 4,000 h.p. 540 volts, with a speed range of 180/360 r.p.m.

From the Australian Iron and Steel Co. Ltd., a contract has been received for the electrical drive for a 2-stand temper mill for the Port Kembla Works, New South Wales. Each stand will be driven by a 1,250 h.p. D.C. motor, and six motors, representing a further 2,100 h.p., serve to drive the coilers and uncoilers. Control exciters, operating in conjunction with a Ward Leonard system, will be used to provide the rapid response and complete stability on which the efficient operation of high-speed mills of this type depends. The mill will be similar in design to the two now in service at the Trostre Works of the Steel Company of Wales. These were the first in this country to run with strip speeds of up to 4,000 ft. per min. and are operating most successfully. They are fully described in an earlier edition of this Journal (*G.E.C. Journal*, Vol. XX, No. 3, July, 1953).

The order placed by Davy & United Engineering Co., Ltd., on behalf of the Broken Hill Pty. Co. Ltd., Australia, for the electrical equipment for an ingot buggy is of special interest. The buggy, which transports hot ingots from the soaking pits to the rolling mill, is operated by two winch motors which serve to reel up or pay-out the haulage rope according to the direction of travel of the buggy. These motors are fed in parallel from a Ward Leonard set, operating in conjunction with control exciters to give precise speed and tension control. The pay-out motor is driven by the tension in the haulage rope and thus acts as a generator to feed power back to the supply. The tension in the haulage rope is maintained by means of a series booster.

The operation of the equipment is completely automatic, the buggy proceeding to any of ten stopping positions as selected by the operation of the appropriate push button on the control desk. Acceleration and deceleration are controlled automatically according to the distance the buggy has to travel. If required, stalled tension is applied automatically to the haulage rope for a short period after the buggy comes to rest. A differential stalled tension is applied at the mill loading position in order to pull the buggy hard against the mechanical stops and operate the mechanism for tipping the ingot.

The buggy will stop at the selected soaking pit even if travelling at full speed in the opposite direction when the selected push button is operated. In such circumstances, controlled Ward Leonard braking is followed by controlled acceleration in the correct direction. Provision is also made for manual speed control from the desk so that the buggy can be run at any speed in either direction and the winch motor can be inched for changing the haulage rope. Overspeed protection, graded at each end of the track to meet the acceleration and deceleration characteristics of the buggy, coupled with the usual sequence and protective interlocking, ensures correct, safe and reliable operation of the equipment.

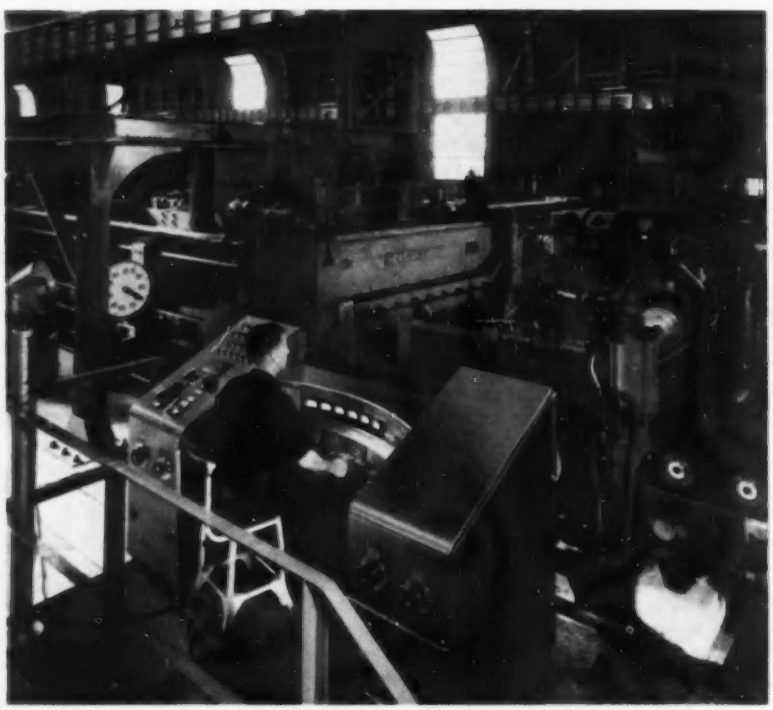


Fig. 47.—The up-cut shear in the 74 in. by ¾ in. cut-up line seen in fig. 46.

Industrial Electrification

PAPER MILL EQUIPMENT.

A complete electrical equipment is being supplied to Imperial Paper Mills Ltd. for converting a paper machine to sectional drive. Two generator sets, driven by 500 h.p. and 415 h.p. D.C. motors, provide power for the couch and press section and for the driers and calender section respectively. The control system will be similar to that previously installed for other machines which have been running with complete satisfaction for many years at these mills. Each section will be driven by a variable-speed D.C. motor, designed to give the required starting torque, which varies widely from section to section. This motor together with the draw control mechanism is mounted on a single bedplate. A complete unit of this type as supplied for the earlier paper machines is shown in fig. 48. On that occasion the motors were of the protected type, but for the new contract forced-ventilation is being used. Automatic draw regulators maintain a constant draw between sections.

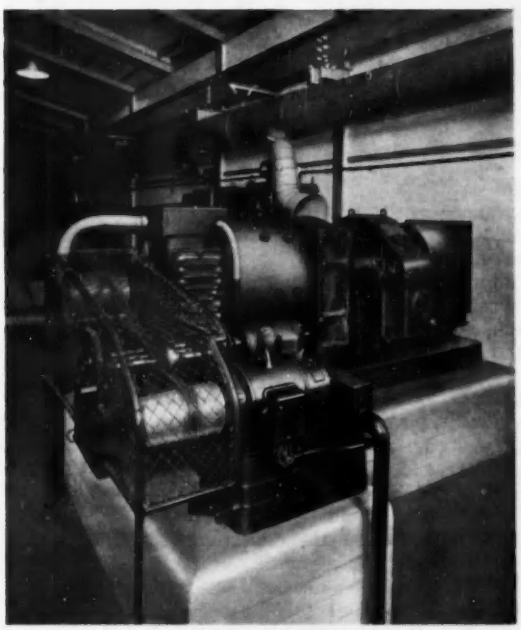


Fig. 48.—Driving unit installed for one of the paper mills of the Imperial Paper Mills Ltd.

Overall speed control is provided by a motor-operated potentiometer which controls the generators of the two motor-generator sets. For the automatic speed regulation within the very close limits necessary use is made of an electronic speed balance control system, which has already proved its worth on two other machines at the mills. In addition to the paper machine drive itself, the contract includes a 285 h.p. motor for the super calender drive.

TEXTILE EQUIPMENT.

Over the past twelve months there has been a marked increase in the orders received for electrical equipment for textile mills overseas. For jute mills in Calcutta 27 motors totalling over 5,200 h.p. are being supplied. Eight of these machines rated at 200 h.p. and two rated at 125 h.p. are for the Budge-Budge Jute Mills, the remainder, together with control gear and L.V. switchgear, being for the Fort Gloster Jute Mills.

A large contract is in hand for the Valika Textile Mills in Pakistan. It includes 290 squirrel cage machines, ranging from 1 to 12 h.p. for a 30,000 spindle plant; 198 loom motors of $\frac{3}{4}$ h.p. and 1 h.p. with all associated control gear; in addition to sub-station equipment which includes three 750 kVA transformers with high-voltage and low-voltage switchgear. Also for export to mills in Pakistan are 310 $\frac{3}{4}$ h.p. loom motors with starters and pilot switches for the Rashid Mills and 139 squirrel cage motors ranging from $1\frac{1}{2}$ to 12 h.p. for the Habib Mills.

A motor and chain drive unit for carding engine drives has been standardised by the Company in conjunction with Renold Chains Ltd. It is intended primarily for converting existing carding engine drives from line shaft to individual electric drive. As shown in fig. 50, it is mounted on the carding engine and takes up no more room than the original drive from overhead line shafting, thus completely avoiding encroachment on floor space. At the same time it provides a fully protected, self-lubricating power transmission system with particularly low running costs.

The advantages of individual drives for carding engines have long been recognised in the textile industry, but formerly the motors have usually been mounted on the floor at the back of the card and consequently have severely restricted the passage ways. Production of the new unit has been made possible as a result of developments in electric motor design and ratings and the full co-operation afforded by the carding engine manufacturers.

The driving motor is a totally enclosed squirrel cage machine designed to give the required starting torque to bring the carding engine up to speed at the rate prescribed by the makers. It is controlled by a direct-to-line starter which incorporates saturable core magnetic overcurrent releases to preclude the

risk of unnecessary tripping during the starting period without prejudicing normal overcurrent protection. The chain transmission is based on experience of high-speed power drives, and by altering the combination of chain wheels and pinions a fine range of cylinder shaft speeds from 168 to 181 r.p.m. is available with a motor speed of 960 r.p.m.

The drive is enclosed in a cast aluminium oil tight case, which is equally suitable for right- or left-hand motor mounting. Apart from the advantages of space saving, the drive is the most mechanically efficient that can be devised and N.P.L. tests have established the transmission efficiency to be 98·5 per cent. with no slip or lost output. Provision is made for stripping or grinding at slow or normal operating speed.

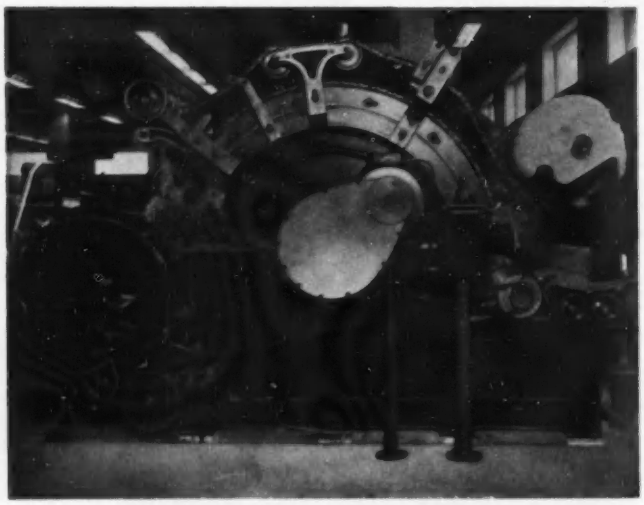


Fig. 50.—G.E.C.-Renold carding engine drive.

ELECTROMAGNETS.

The demand for large magnets has been well maintained, a notable feature being the number required for service as suspension separator magnets. These orders include ten magnets for the National Coal Board ranging in size from 36 in. dia. to 64 in. dia. which will be used to extract tramp iron, etc., in order to protect the plant used in the subsequent treatment of the coal. For lifting duty many magnets in sizes up to 65 in. dia. are in hand for steelworks in this country and overseas, including one order for nine of 65 in. dia. for the Indian Iron and Steel Company.

In previous progress reviews, mention has been made of the magnetic sweep for use on airport runways. A 72 in. sweep in which the magnet is energised from a 1·5 kW, engine-driven generator (fig. 49) is now available and was demonstrated at the Society of British Aircraft Constructors' Exhibition at Farnborough last year. The magnet is controlled by push buttons arranged alongside the tractor driver and connected to the magnet through a tough-rubber-covered cable. Adjustment of the gap between the magnet and the runway up to a maximum of 4 in. is effected by handwheels located at each end of the magnet. For normal operation the sweep is towed at 5 m.p.h., and a 3 in. air gap is advised. For higher towing speeds, up to 10 m.p.h., this gap should be reduced.

LINE-CONTACT CIRCUIT-BREAKERS.

A new range of airbreak circuit-breakers, covering normal ratings up to 1,600 amp. per pole, has been designed and marketed. A modified form of the line-contact principle which has proved so successful is used, but the new design eliminates the V-grooves in the block and the V-shaped leading edge of the blades.

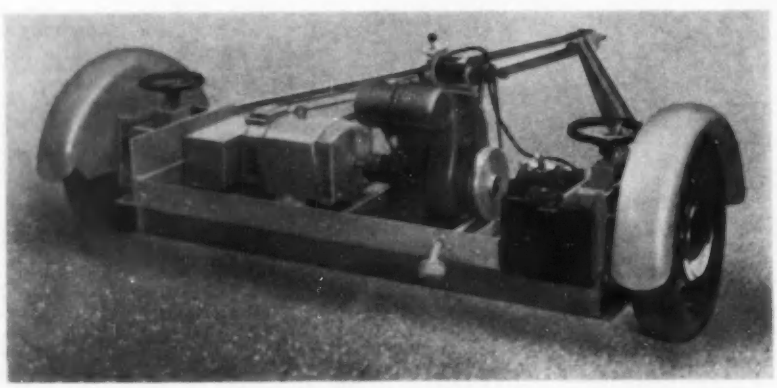


Fig. 49.—A 72 in. magnetic sweep with cover removed to show arrangement of the engine-driven generator.

These " Compact " circuit-breakers can be mounted on open frameworks (fig. 51), as an alternative to the more conventional panels. A special breaker of this type has been supplied recently with a rating of 5,000 amp. per pole in a triple-pole form and solenoid-operated for opening and closing. By mounting this circuit-breaker

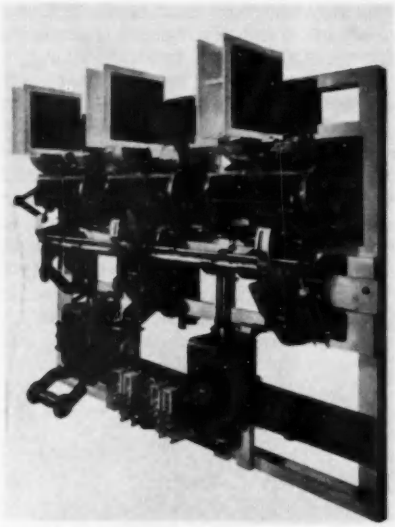


Fig. 51.—5,000 amp. triple-pole circuit-breaker mounted on angle-iron framework.

on an angle-iron framework, a saving of 450 lb. nett weight was achieved in comparison with mounting on a conventional slate panel.

PROTECTION OF SOLENOIDS.

In the past year Chamberlain & Hookham Ltd. has developed a relay for the protection of solenoids used in electrically-operated circuit breakers. Normally the solenoid is arranged to break its own no-volt release circuit, but in the event of mechanical obstruction or other abnormal condition the short-rated solenoid would suffer damage from prolonged energisation. The Chamberlain & Hookham Relay Type S has a directly heated bimetallic element which is connected in series with the solenoid and hence carries the energising current. Prolonged current flow through the relay causes flexure of the bimetallic element and after a preset period a latch is disturbed, allowing a mercury switch to rotate under gravity and interrupt the no-volt release circuit. The switch is rated at 10 amp, 250 volts A.C. or D.C., and carries a device which indicates relay operation. The case can be arranged for projecting or flush mounting and is approximately 3 in. by 4 in. by 4 in.

TIME-DELAY SWITCHES.

Two time delay switches have been introduced by Chamberlain & Hookham Ltd. Type EA is a spring-driven unit which is set by hand to any value of time interval up to 5 min. or alternatively up to 15 min. At the end of the preset time two double-break switches open, four terminals being available for circuit connection. The switch is rated to make and break 10 amp at 250 volts A.C. Type MA is a motor-driven unit which can be arranged for time intervals up to seven days with a variety of intermediate values. One double-break switch is available to interrupt a circuit at the end of the preset interval. This switch is rated to make or break 10 amp at 250 volts A.C.

POWER FACTOR CORRECTION.

Chamberlain & Hookham single- and multi-stage power factor correction relays are now available in front-connected cases for wall mounting. The principle of operation was described in an article in the *G.E.C. Journal* for April, 1955, in which a single-stage unit for wall-mounting was illustrated.

DRY-PLATE RECTIFIERS.

Increasing use is being made of dry-plate rectifiers (fig. 52) for a growing range of industrial purposes where previously motor-generators were employed. Equipment rated up to 40 or 50 kW has been supplied for operating large lifting magnets, hoists, and special welding apparatus. In the higher ratings the rectifier transformer and other wound components are oil-immersed in totally enclosed steel tanks which,

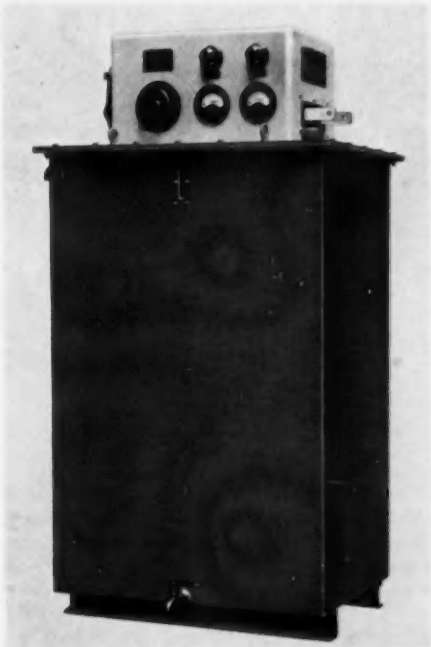


Fig. 52.—6 V., 500A plating rectifier, transformer and control unit.

according to size and power rating, can be additionally cooled by the use of piped tanks, or the circulation of water round the tanks.

RECTIFIERS FOR SCHOOL LABORATORIES.

Two special rectifier equipments have been developed to meet the needs of school laboratories, one for the smaller laboratory, the other for large technical schools. The smaller apparatus (fig. 53) is arranged for a single-phase input supply of 200/250 volts, 50 cycles, though other voltages can be supplied when required. It has an output of both A.C. and D.C. of 0-14 volts at 40 amp. extending to 18 volts at 32 amp. The equipment consists of a double-wound earth-screened transformer arranged with suitable ageing taps and nominal voltage adjustment, together with a full-wave bridge type selenium rectifier. The output from the transformer is controlled by a moving brush auto-transformer regulator which enables the output voltage and current to be adjusted as required. A two-position switch enables either the A.C. or D.C. output voltage to be selected.

The equipment for use in large technical schools (fig. 54) is suitable for operating from a 240 volt, 50 cycle, single-phase supply and has two A.C. circuits and three D.C. circuits. Two circuits are for 12 volts, 40 amp, one for A.C. the other D.C.; two circuits are for 24 volts 40 amp, one for A.C. the other D.C.; and the remaining D.C. circuit is for charging six lead acid cells at 4 amp. The apparatus comprises a double-wound earth-screened transformer having 5 secondary windings and tappings to give nominal voltage adjustment. Three of the windings supply full wave bridge selenium rectifiers; the remaining windings are connected to suitable terminal blocks to provide the A.C. output.

MOTORS FOR ATOMIC FACTORY.

An important contract for a large number of special high-speed motors is nearing completion. These are for use at the United Kingdom Atomic Energy Authority factory at Capenhurst for driving plant units which separate uranium 235 from uranium 238. The motors are of unusual and difficult construction and their development has for several years been a major item in the technical and manufacturing programme of the Fractional Horsepower Motor Works.

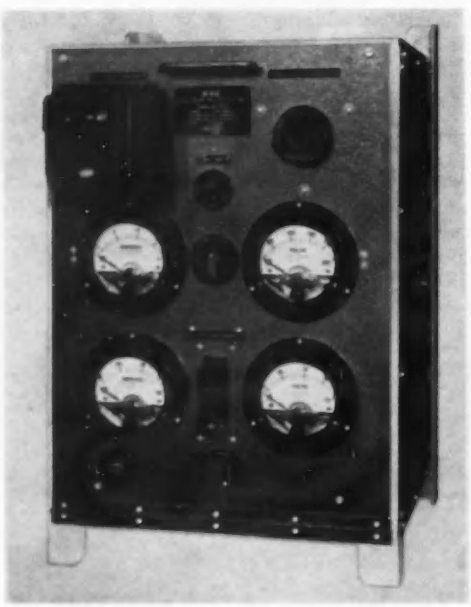


Fig. 53.—Rectifier equipment for the smaller laboratory.

Fig. 54.—A unit for large technical schools.

Transport

RAIL AND ROAD.

The £1,200 million modernisation plan published by British Railways early in 1955 forecast the eventual elimination of steam traction in this country and its replacement with electric and diesel power. In November the first orders under this programme were placed by the British Transport Commission, covering three basic types of diesel locomotives for express, mixed traffic and branch line duties. The Company is supplying twenty diesel-electric power equipments for Bo-Bo locomotives to be built by the North British Locomotive Co. Ltd., ten of which are for main-line mixed traffic and ten for branch line services.

For the main-line locomotives, the power equipment will comprise a pressure-charged vee 12-cylinder N.B.L./M.A.N. 1,000 h.p., 1,500 r.p.m. engine direct-coupled to a G.E.C. main generator with overhung auxiliary generator. Each axle will be driven through Wiseman resilient gears by a nose-suspended, forced-ventilated traction motor. Control will be by a combination of generator field control and variation of engine speed, the latter being effected by three air-operated pistons acting through levers on the engine governor to provide eight engine speed steps. Automatic torque control through an oil servo regulator will be available on all controller notches. These locomotives are designed for a maximum axle-loading of 18 tons and a top speed of 75 m.p.h. There will be a driving cab at each end of the locomotive.

The branch-line locomotives will be of similar wheel arrangement to the main-line design, but will have a driving cab at one end only, with duplicated controls for driving from either side. They will be powered by a 16-cylinder Paxman YHXL 800 h.p., 1,250 r.p.m. engine direct-coupled to a flange-mounted G.E.C. main generator with overhung auxiliary generator. Forced-ventilated, nose-suspended traction motors will drive the axles through Wiseman resilient gears. The control system will be generally similar to that of the main-line locomotives. In the branch line design the axle load will be 17 tons and the maximum speed 60 m.p.h. Both types will be arranged for multiple-unit working.

During the period under review, the fifteen diesel-electric shunting locomotives for the North Eastern Region of British Railways have been brought into service. Each comprises a 350 h.p. Blackstone diesel engine direct-coupled to a generator which supplies two axle-hung double-reduction geared traction motors. A full description of these locomotives has already appeared in this journal (*G.E.C. Journal*, Vol. 22, No. 3, pp. 209-218, October, 1955).

Further trolleybuses using G.E.C. electrical equipment have entered service in the City of Cardiff, where a fleet has been in operation for several years. One of the latest single-deck trolleybuses is seen in fig. 55.

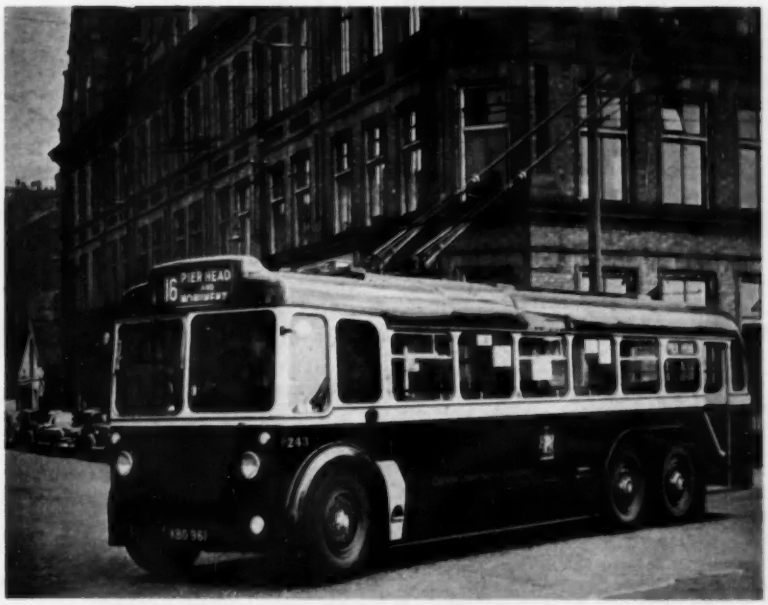


Fig. 55.—One of the new Cardiff trolleybuses.

The manufacture of the electrical equipment for the rolling stock for service on the Liverpool Street to Southend line in the Eastern Region of British Railways is proceeding. This contract covers thirty-two 4-coach trains of the semi-express, limited stop type. Each will comprise two driving trailers between which are coupled a motor coach and one trailer. Toilet accommodation will include electrical water heating equipment.

A further contract has been placed by the British

Transport Commission for the complete electrical equipment for fifty-seven new 3-coach multiple unit trains to replace existing rolling stock on the Euston-Watford service, London Midland Region. Each 3-coach unit will comprise a motor coach, trailer and driving trailer. These equipments mark a departure in design from those previously supplied, and are not intended for multiple-unit working with existing rolling stock. The electro-pneumatic contactor control equipment will be mounted on the underframe, thereby giving more passenger accommodation than is available on the existing stock where this equipment is mounted in compartments. Series parallel control is provided for the four motors, each of which has a continuous rating of 135 h.p. The motors are grouped in pairs, those of each pair being permanently in parallel. There will be four running speeds, two weak-field steps being provided in the parallel connection. The equipment is designed for an initial rate of acceleration of 1·27 m.p.h. per sec. and a maximum speed of 70 m.p.h. A new type of shoe gear is being developed for a number of these trains in order to give improved current collection and eliminate noise. Lighting and all control circuits are fed from a low-voltage supply. Since 1926 electrical equipment has been supplied for 25 motor coaches, 25 driving trailers and 22 trailer coaches operating on this service, the new order being the fourth to be fulfilled.

For three prototype tube trains, which will be of steel construction with aluminium panelling and incorporating rubber in the suspension, the London Transport Executive has placed an order for thirty-two 575 volt traction motors. The motors will have a continuous rating of 80 h.p. and will be generally similar to the earlier design, of which over 900 have been supplied. They will be smaller and lighter and will be designed to give an improved train performance over the pre-1938 stock without entailing any increase in the peak current demand. A wide range of field control will be provided and operation on full field will be confined to the initial acceleration period. Self-ventilation will be used and roller bearings fitted to the armature and in the axle-suspension sleeve. Of the 21 vehicles in the prototype trains, 15 will be motored, one motor being mounted in each bogie.

The experimental camshaft control equipment, to which reference was made in this review last year, has successfully completed its trials on the London Transport Executive's tube service. Essential data have been obtained from the rigorous testing undertaken at the Works and further development is in progress to make this equipment suitable for service on higher-voltage systems.

At the request of the London Transport Executive, investigations have been made into the problems associated with regenerative braking of tube trains using compound wound motors. As a result an order has been placed for two experimental control equipments for this service. They will be tested on a 2-car train made up from existing stock on which motors will be modified to operate with the new control equipment.

Also during the year, control receptacles and jumpers using butt contacts have been brought into production. A 32-point type is shown in fig. 56. It has been designed to simplify coupling up of trains and to ensure good contact at all points and positive locking of the jumper in position. Other developments include improvements

Fig. 56.—A 32-point jumper with butt contacts.

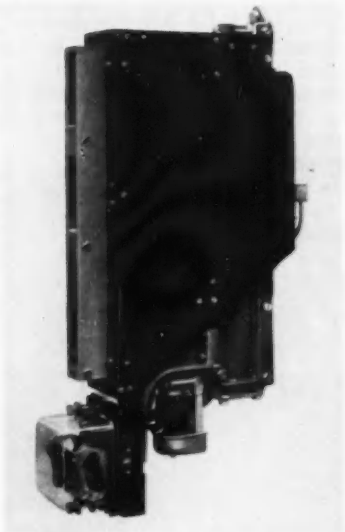


Fig. 57.—A typical traction type contactor with butt contact interlocks mounted on the front.

in certain details of apparatus to ease inspection, a typical example being seen in fig. 57, which shows butt contact interlocks mounted together with the electro-pneumatic valve on the front of a contactor.

RAILWAY SIGNALLING.

Improvement and modernisation of railway facilities at home and abroad are involving numerous resignalling schemes. Where lines are being electrified it is necessary to isolate the signalling apparatus from the effects of stray D.C. emanating from the traction supply. This work is being carried out by The Siemens and General Electric Railway Signal Co. Ltd., on the Shenfield-Chelmsford and Shenfield-Southend extensions of the Eastern Region Liverpool Street-Shenfield 1,500 volt D.C. electrification.

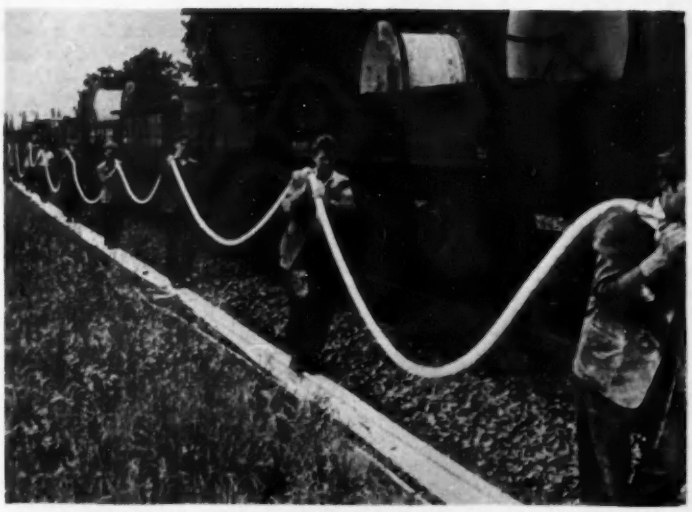


Fig. 58.—Laying cable for the automatic colour-light signalling on the electrification extension to Chelmsford.

Between Shenfield and Chelmsford (9½ miles) the existing D.C. track circuits are being converted to capacitor-fed single rail or double-rail operation, using A.C. double-element vane type track relays. There will be 29 single-rail and 45 double-rail track circuits, the former being installed where the traction conditions enable one rail to be used exclusively for the signalling circuit, the second being a common return for traction and signalling currents. All signals except those within the control limits of Shenfield, Ingatestone and Chelmsford will be controlled automatically over the new A.C. track circuits. New relay rooms are being provided at Ingatestone and Chelmsford signal boxes, equipped with new power switchboards, plug-in relays, lever locks, and fuse and terminal racks, necessitating complete rewiring.

This contract includes a complete power distribution system at 650 volts, 50 cycles A.C., new multi-core signalling and power cables and three telecommunication cables over a distance of ten miles. The cable route and cable laying were completed by last autumn and the trackside equipment is now being installed with a view to the complete installation being ready for the summer services this year (fig. 58 and 59).

Similar work is in hand between Shenfield and Southend Victoria (20½ miles). This involves the supply and installation of 169 A.C. track circuits, 111 of which are double-rail with impedance bonds ; also the associated power supply cable for 650 volts A.C. and four telecommunication cables—one 8-pair and three single-pair. All existing signals and the D.C. lever locks at ground frames are being immunised against the D.C. traction current. Approximately 115 apparatus cases and 800 plug-in relays of various types are being provided. New relay racks will be installed at Southend and Wickford signal cabins, both of which are being rewired.

In Glasgow, outdoor work has been completed and the indoor installations are under way for colour-light

Fig. 59.—A section of completed cable route on the Chelmsford electrification extension.

signalling with continuous track circuits on some five miles of the steam-operated low-level suburban lines running east and west from Glasgow Central Station. Relay interlocking control panels with thumb switches for operating signals will be installed above the mechanical points lever frames at two signal boxes, the thumb switches being mounted on diagrams of the lines involved, and placed at the positions corresponding to the location of the signals they control. The mechanical frames at these boxes are being fitted with lever locks and circuit controllers. All relays, including interlocking relays, will be of the latest plug-in type. The 56 double-rail A.C. track circuits are capacitor-fed, with double-element plug-in type vane track relays.

A telephone system with instruments at all main running signals is being provided.

A new Centralised Traffic Control installation is nearing completion for the Rhodesia Railways, where the equipment provided in 1951 between Heany Junction (near Bulawayo) and Gwelo was the first C.T.C. on the African continent. This form of control is now being extended to the main line to Livingstone, and S.G.E. was awarded a contract for equipping the 120-mile section between Gwaai and the Rhodesian coal mining area at Wankie. On the 50 miles between Dett, where the control panel will be located, and Wankie the points will be power-operated, in contrast with the hand-operation on the earlier Heany Junction-Gwelo installation. This will increase considerably the capacity of the line, over which most of the Rhodesian coal traffic is routed.

A development of interest in connection with S.G.E. activities in the municipal field has been the marketing of the Duncan-Miller "60" parking meter. This instrument embodies many unique features in an ingenious design of pleasing appearance. It can be supplied for measuring off periods of time as required, times and rates of payments being arranged to suit the circumstances of individual installations. The meter is self-winding by the action of turning a handle to set the timing pointer after a coin has been inserted. Continuous indication of unexpired time is given by the pointer. When the time paid for is ended, a "Time Expired" flag is displayed so as to be visible from either side of the meter. A window enables the last coin inserted to be seen. Misuse of the meter causes an "out of order" sign to be displayed.

Equipment is in course of installation on the South African Railways for the remote control of points and signals at two crossing loops, at Kromellenboog and Wildhoen, on the Cape Town-Johannesburg main line. They will be controlled from a C.T.C. machine at Britten, approximately half-way between the two loops, which are sixteen miles apart. Other main items of equipment for the installation are colour-light signals, direction route indicators, point machines, and track-circuiting for the loops. Three diesel-generator sets are being provided for power supplies.

MARINE ELECTRICAL EQUIPMENT.

During the year it was announced that a successor is to be built to the well-known research ship "John Biscoe". The Company has received through Messrs. J. Charters an order for the diesel-electrical propulsion and auxiliary power equipment of this new 800-ton vessel, which is being built by Fleming and Ferguson Ltd., of Paisley, for the Falkland Islands Dependencies Survey. The equipment comprises two main engine-generator sets powered by National Gas diesel engines, supplying a 1,450 s.h.p. double-armature motor driving a single screw.

Fig. 60.—Lighting in the smokeroom of the new Shaw, Savill & Albion liner, "Southern Cross."

The system of control is a development of that used with marked success for the two pilot vessels which have been in service for the Mersey Docks and Harbour Board for the past two years. For the new vessel, control up to half speed will be on the Ward Leonard system and from half speed to full speed by accelerating the diesel engines to their top speed. Engine speed from half to full speed is controlled by motor-driven governors. The governor motor is controlled through limit switches by movement of the main propulsion motor controller handwheel. A further step on the

main controller increases the speed of the propulsion motor by shunt control to emergency maximum.

The advantage of engine speed control lies in the economy which can be effected in fuel consumption, since at low speeds the engine losses are reduced.

Both sequences of control are effected from a single controller and apart from minor variations occasioned by wind and weather, the propeller speed for any given position of the controller will always be the same.

Numerous orders in hand for lighting installations in large passenger ships emphasise the leading position held by the Company in this field, and during the period under review an interesting application of Osram architectural lamps for decorative lighting was made in the smokeroom of the new Shaw, Savill & Albion liner " Southern Cross " (fig. 60). Of the large cold cathode installations now in progress, that in the new Canadian Pacific liner " Empress of Britain " alone will account for over two miles of Osram tubing. This is more than twice the length of tubing supplied for the same line's " Empress of Scotland ", which some five years ago had the largest cold cathode installation afloat. The popularity of this lighting among passengers has therefore been well tested and has had its influence on the decision to use the same combination of ivory and gold tubes in the new ship. The favourable opinion was supported by the results of tests carried out by the Canadian Pacific Company to study the appearance of cosmetics and clothing under this form of lighting. Other new ships in which the Company is responsible for the lighting of public rooms with cold cathode or tungsten sources are the " Nevasa " of the British India Line, the " Bergensfjord " of the Norwegian America Line and the " Reina del Mar " of the Pacific Steam Navigation Co. Ltd. References to the A.C. generating plant, switchgear and motors being supplied for the " Bergensfjord," the first passenger ship built in Great Britain with all its auxiliaries operated on A.C., have been made in previous reviews of Progress.* The tungsten fittings for the lounges of this ship have been designed in accordance with current trends in Norwegian decorative taste. In the first class and tourist lounges the cold cathode lighting will be provided with electronic dimming control to give a three-colour sequence, or dimming cycles of the individual colours.

The " Reina del Mar " is being supplied with comprehensive sound equipment facilities for entertainment, announcements and crew instructions. A 175 W amplifier in the main 3-bay rack assembly will broadcast radio programmes fed from a communications type receiver mounted in the same rack, and facilities have been provided for making tape recordings of transmissions received at an unsuitable hour, for rebroadcast later. Microphones in the first-class dining saloon and lounge will enable music by the ship's orchestra to be broadcast to all parts of the ship through a 30 W amplifier in the main rack. A 60 W amplifier for speech only will feed the loudspeakers at boat stations and in the officers' and crew's quarters. Equipment for reproduction of pre-recorded tapes and gramophone recordings, together with a compère's microphone, is being provided for the music room.

The installation comprises 170 loudspeakers connected in four groups. Many of them are 10 in. instruments for mounting behind grilles in wall panelling and deckheads, the grille designs being varied to match the decorative schemes in different parts of the ship. Others are designed with minimum front projection for mounting in alleyways of limited width, and a number of units are weatherproofed for installation on open decks.

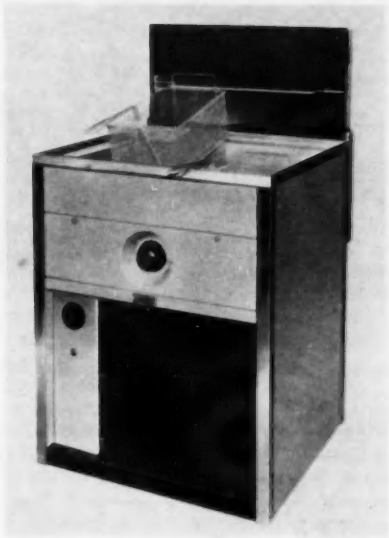


Fig. 61.—A compact quick fryer for ships' galleys.

Microphones and loudspeaker group selection keys are provided for the captain and the purser, their announcements having first and second priority respectively on all circuits. Selection of circuits from these control units automatically ensures full volume restoration on all loudspeakers.

A recent addition to the range of marine D.C. cooking equipment is a compact quick fryer with thermostatic control. The fryer is built as a single-pan unit (fig. 61). Two or more units, each with a maximum loading of 9 kW, can be mounted together to form a multi-pan fryer to meet requirements. Cartridge elements, which can be readily withdrawn without the pan having to be emptied, provide direct heating of the fat or oil.

AERONAUTICAL EQUIPMENT.

Among orders for aircraft pantry equipment received during the year has been one from the Scandinavian Airlines System (S.A.S.) for 57 air-circulation ovens, some of which will be used on the Douglas D.C.6B

* *G.E.C. Journal*, Vol. XX, No. 1, p. 28, January, 1953; and Vol. XXI, No. 1, p. 38, January, 1954.

aircraft operating on the Polar route from Copenhagen to Los Angeles. One oven is installed in each aircraft, providing capacity for serving 30 to 40 meals at a time. Numerous airlines are now using ovens of this type, which enable varying numbers of passengers to be catered for economically. Sabena Belgian Airlines have recently ordered twenty ovens for replacing existing equipment in aircraft and for new

Fig. 62.—Combined hotcup and snack cooker for aircraft.

installations. Reliability is an essential feature of such equipment and the satisfactory performance of the ovens in this respect is indicated by the fact that one large user, K.L.M. (Royal Dutch Airlines), finds that inspection is necessary only at intervals of 1,000 flying-hours.

New aircraft for British Overseas Airways and British European Airways are being supplied with the Company's aircraft galley equipment. The aircraft rapid water boiler illustrated in last year's Progress article is being installed in the first Viscount 800 Series. This boiler is to be standardised for all B.E.A. aircraft. The galley of the first Britannia long-range propellor-turbine airliner (fig. 66), which has been undergoing proving flights preparatory to entering B.O.A.C. service, is equipped completely with G.E.C. cooking and water-heating appliances, comprising two air-circulation ovens, two 2-gallon urns, eight hot food and beverage containers and three hotcups. In addition the Company has supplied four ½-gallon water heaters for the toilets, the cabin humidifier, eight different types of cabin warning signs, and 92 spotlight reading lamps developed in conjunction with the Bristol Aeroplane Co. Ltd., for providing localised illumination at individual passenger seats.* On one proving flight, when the return journey between London Airport and Idris (Tripoli) was made in a day, a round trip of 5,800 miles, 95 hot breakfasts and 95 dinners were served from the galley. Similar equipment will be supplied for the 15 B.O.A.C. Britannias of Mk. 100 and 17 of Mk.300.

The serving of hot drinks and soup to individual order has been much appreciated by airline passengers since the hotcup was introduced for this purpose. As an extension of this idea, a combined hotcup and snack cooker has been developed (fig. 62). Comprising an 800 W heater unit, a saucepan and a frying pan, it provides for cooking small quantities of bacon, eggs or other fried foods as well as for preparing beverages. An order for these units has recently been received from Scandinavian Airlines System.

A new type of airborne rotary transformer for use in aircraft has been designed for the Royal Aircraft Establishment, Farnborough. A special feature is the supply of a small amount of D.C. power for radio operation by rectifying A.C. produced in a pole-face

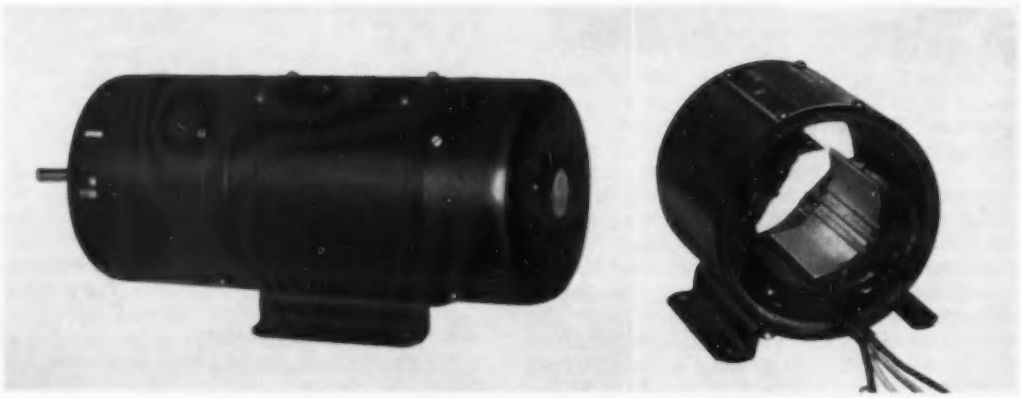


Fig. 63.—Aircraft rotary transformer with pole-face winding for an A.C. output which can be rectified for low-power D.C. requirements.

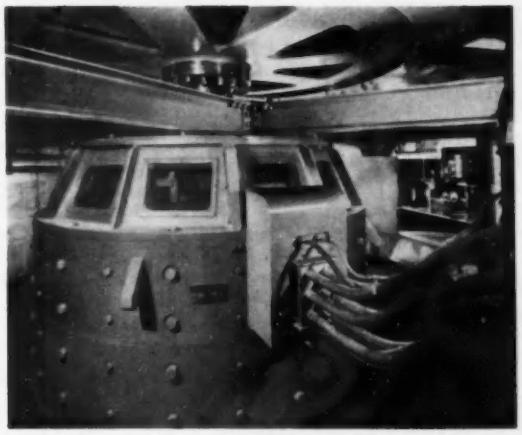


Fig. 64.—1,350 h.p. motor for driving the man-carrying centrifuge.

winding. This represents a major saving compared with previous types of rotary transformer in which the small power requirements were met by an extra armature winding and commutator. The pole face winding has precluded the use of skewed slots on the armature, but the difficulty of resultant ripple on the armature outputs has been overcome with the help of a graded air gap and special pitching of the armature coils (fig. 63).

MAN-CARRYING CENTRIFUGE.

The very high values of acceleration to which pilots are subjected during manoeuvres in modern aircraft have made necessary the investigation of the effect of the resulting forces on the human body and on the various mechanisms within the aircraft itself. For this purpose an electrically driven centrifuge has been installed at the R.A.F. Institute of Aviation Medicine, Farnborough, and was brought into operation last May. The contract for the centrifuge was placed with M. B. Wild & Co. Ltd., the whole of the electrical plant and control gear being supplied by the G.E.C.

The centrifuge is capable of producing accelerations up to thirty times that due to gravity and is driven by a vertical spindle D.C. motor (fig. 64) rated at 1,350 h.p., 54 r.p.m., a maximum power 50 per cent. in excess of this being developed momentarily at the end of acceleration as the final speed is reached.

Arrangements are made for either automatic or manual operation, and when testing human reactions an overriding control is afforded to the subject in the test car. The system of control is necessarily very complex and has already been fully explained in a previous issue of this journal (*G.E.C. Journal*, Vol. 22, No. 3, July, 1955).

TRANSPORTABLE OXYGEN GENERATING PLANT.

Another interesting Air Ministry contract, received through the Butterly Co. Ltd., covered electrical equipment for transportable oxygen generating plant mainly for service on airfields. Twelve equipments have already been supplied and a further eight are in hand. They are designed for service in any part of the world in ambient temperatures ranging from —25 deg. F. to 125 deg. F.

The general layout of the equipment is shown in fig. 65 from which it will be seen that all the components are mounted on a fabricated steel raft with skids to enable the complete unit to be manoeuvred into position on rough ground.

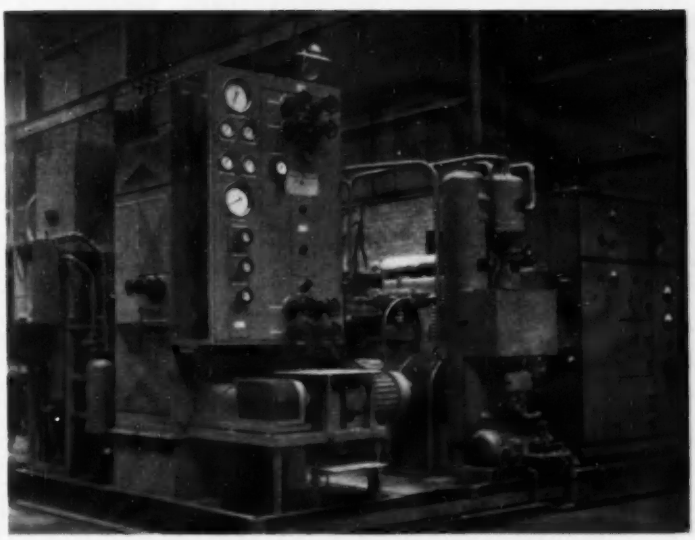


Fig. 65.—Transportable oxygen generating plant.

The air compressor is driven by a diesel engine which also drives a 37·5 kVA alternator for supplying power for the motors operating the refrigerator compressor, oxygen pump and air purifier. Automatic voltage regulation of the alternator is effected by a carbon pile regulator, while provision is also made for emergency hand control. All the associated switchgear for the alternator, motors and heater circuit is housed in a cubicle type switchboard.

In order to facilitate transport over long distances, the supporting raft can be split into three sections, the interconnecting cables for the electrical equipment terminating in plug and socket connectors. The control board is supported on resilient mountings to absorb any vibration from the diesel engine and shock loads produced when dragging the equipment over rough ground or during loading and unloading operations.

[Courtesy B.O.A.C.

Fig. 66.—Galley equipment in the Bristol "Britannia".

Electronic Control

PRINTING PRESS CONTROL

Precise " inching " control of printing press driving motors is of particular importance in order that setting up of a press may be carried out quickly and accurately. For this service a new amplifier (fig. 67) has been produced. It incorporates a transductor with characteristics such that an even more exact inching control is afforded than was previously possible. Also for the printing industry is a new device for initiating the splicing of a new roll of newsprint on

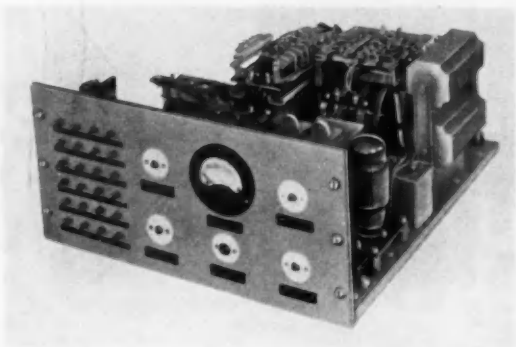


Fig. 67.—Electronic amplifier for the control of printing presses.

to the expiring roll while the press is running. In a previous Progress review (*G.E.C. Journal*, Vol. XXI, No. 1, p. 40, January, 1954) mention was made of a Roboreel developed in conjunction with Beaverbrook Newspapers Ltd., for use with the Witton-James-Wood Autopaster for matching the peripheral speed of the new roll to that of the paper passing into the press. A new electronic Roboreel has been developed for use in conjunction with the equipment then described, and automatically initiates rotation of the new roll and the subsequent splicing operation at the right instant. Formerly correct timing depended on the skill of the operator.

CONTROL OF MOTOR DRIVES.

An interesting application of electronics to the speed control of a motor is provided by the equipment illustrated in fig. 68, which has been recently supplied for a Yorkshire water works for use in the purification plant for town water supply. The rate at which the chemical is added must be kept strictly proportional to the rate of flow of water through a pipe. The chemical is fed by a motor-driven unit, while the rate of flow of the water is measured by a manometer in conjunction with a venturi in the pipe. The manometer actuates a speed-setting potentiometer in the electronic device which controls the speed of the motor. This potentiometer is specially designed to operate accurately with the very small torque available from the manometer.

It is often essential to provide for close matching of speeds of driving motors, and for this purpose a robust type of relay has been developed. Its operation depends upon the difference between two voltage signals and the equipment is designed to initiate the appropriate speed correction if this difference exceeds 2 per cent of the maximum value of the signal. The relays are fed from two transductors and can, therefore, be made sufficiently robust to withstand normal handling and changes in climatic conditions without readjustment becoming necessary.

In certain processes there is a need for an overcurrent limiting device which can be easily and accurately adjusted and will operate at a much smaller rise in current than is necessary for overcurrent trips of orthodox design. For example, in drilling small-diameter holes of appreciable depth it is desirable to

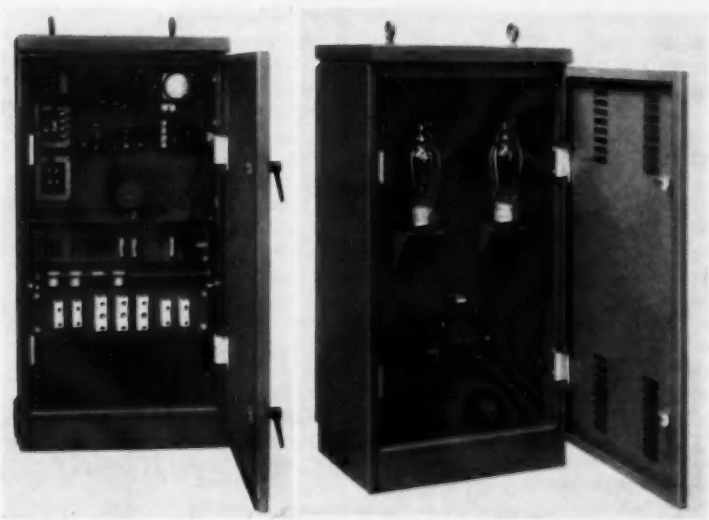


Fig. 68.—Front and rear views of the electronic control device for a Yorkshire water works.

stop the machine if the drill shows signs of binding, otherwise breakage of drills would be excessive. For such duty an electronic overcurrent relay has been developed. It will operate with an increase in current of only 10 to 20 per cent, the overcurrent setting being easily adjusted by means of a rotary potentiometer.

PHOTO-ELECTRIC EQUIPMENT.

At the Brierley Hill Works of Richard Thomas & Baldwins an electronic equipment is used to prevent lateral movement of steel strip when reeling. The faces of the coils must be kept as flat as possible since any unevenness would be likely to give rise to defects which would interfere with subsequent processing of the metal. Any displacement of the strip during reeling is rectified by a tilting roller the driving motor of which is arranged for Ward Leonard control. The Ward Leonard generator is excited by thyratrons, under the control of a photo-electric cell which detects any lateral movement of the strip. In operation this equipment has achieved an accuracy of reeling of the order of $\pm$ 0·01 in.

For the automatic control of electric lighting installations by continuously monitoring the strength of the daylight, a new photo-electric control unit has been produced (fig. 69). Artificial lighting is switched on automatically should the daylight fall to a level at which normal activities could not be carried on safely and efficiently, and is switched off immediately the daylight becomes adequate. Considerable economies can be effected by using this equipment in large buildings, institutions, streets, marshalling yards, airports and the like by ensuring that artificial lighting is used only when the need arises.

It is sometimes difficult to accommodate a complete photocell amplifier unit at the place where the photocell is required, and to meet these conditions a new equipment has been designed comprising separate cell housing and main relay amplifier units. The cell housing, measuring only 4½ in. high by 2¾ in. deep by 1⅝ in. wide, can be situated up to 300 ft. from the main relay amplifier.

Fig. 69.—Daylight photo-electric control unit.

A new medium-range projector incorporates a super purity anodised aluminium reflector instead of a lens. Suitable for a wide range of photo-electric applications, it has a range up to 48 ft. with white light and up to 32 ft. with infra-red light.

Plastics

Although the weekly output of the Witton Moulded Insulation Works has reached 2½ million mouldings incorporating, in moulding and assembly, over 4 million metal parts, the demand within the Company and from outside firms continues to increase steadily so that further extensions have proved necessary. These are now in course of erection, while

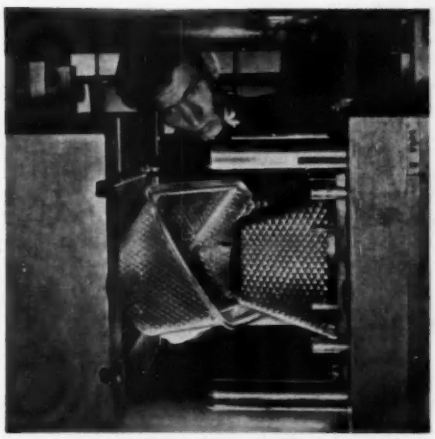


Fig. 70.—Moulding of street lanterns in "Diakon" on a 32 oz. injection press.

additional machines have been installed for the processing of thermo-plastics, and tool room facilities for making the moulds have been improved.

Of the wide variety of mouldings produced, those in polystyrene for portable radio sets are of interest in that they are subsequently painted and must, therefore, be strain-free. This has been achieved by special apparatus to give precise control of the weight per charge and of the mould temperature. Masks for the 17 in. television sets are now in production, while a

Fig. 71.—Assembly of a 20/20 Post Office terminal block.

manufacturing technique, developed in conjunction with the exterior lighting engineers, has made possible the production of lantern enclosures in Diakon (fig. 70).

Thermo-setting plastics are still used for the bulk of the production and increasing use is being made of automatic cycle control with a consequent improved consistency in quality.

For a converter unit, which is being produced to enable existing television sets to receive commercial television programmes, the cabinet is moulded in two halves from a single two-impression mould. By using a new pelleting machine which produces pellets of suitable size for dielectric pre-heating, an outstandingly high rate of production has been achieved.

Fig. 72.—Accumulator container moulded in Im-Plast.

The continued increase in the demand for Mutac switches for both home and overseas markets and the extensive orders for the 20/20 Post Office terminal block (fig. 71) are being fully met by the introduction of improved methods and layouts so that production on other assembly lines remains undisturbed.

The range of products using bitumen-based materials has been extended to include a well-bottom cistern shell which competes with the standard high-level cast-iron unit. The layout of the presses and use of automatic timing and temperature control in the production of this cistern are notable achievements in moulding.

A licence has been obtained for the production of mouldings from a new material which has been developed in the U.S.A. by The Richardson Company and is known under the Registered Trade Mark "Im-Plast". It has a rubber base, is stronger than ebonite and has the added advantage of a shorter curing time. The immediate outlet for this material is expected to be in the production of accumulator containers (fig. 72) where resistance to acid and mechanical strength are of vital importance. It is, however, likely that the low cost of this material, coupled with the high rate at which mouldings can be made, will lead to its extended use in the future.

Industrial and Process Heating Equipment

Fig. 73.—New heat treatment shop at Uddeholm Ltd., Birmingham.

PROCESS HEATING.

Recent process heating installations include that at the Birmingham firm of Uddeholm Ltd., where a new heat treatment shop has been equipped throughout with G.E.C. furnaces and ancillary gear (fig. 73). The installation, which consists of five salt-baths, two forced air-circulation furnaces, one horizontal batch furnace and a low-temperature oven, is designed for the complete heat treatment of the full range of carbon steels in the form of hot and cold working tools.

Four quench tanks provide for oil and water quenching, and the work is carried out in small charges, thus enabling the heat treatment to be carried out under laboratory conditions of control.

A gas carburising furnace for the treatment of heavy engine gears, installed at Vickers Armstrong Ltd., Newcastle, is rated at 30/90 kW and will handle charges of up to 15 cwt. (fig. 74). The carburising atmosphere is generated from liquids which are pumped directly into the furnace chamber for a time sufficient to give case depths of up to 0·100 in. After treatment the gears are transferred to a sealed chamber and allowed to cool under a static atmosphere of town gas.

Fig. 75 shows a 75 kW bell furnace now in use at Pirelli-General Cable Works Ltd., Eastleigh, for bright-annealing copper wire in coils. Three bases are provided, each supporting a fan for re-circulating the gas atmosphere within the hood covering the charge. The atmosphere is generated from town gas and is confined within the hood by means of an annular seal of liquid metal.

A 120 kW furnace designed for bright annealing steel strip in lengths has been developed. This furnace is mounted on rails and can be moved into position over the charges, which are loaded on four sites. The charge is treated in burnt town gas under a steel hood effectively sealed by means of a sand channel.

A high temperature, high vacuum furnace of 10 litres capacity has been constructed. It can reach 1,700 deg. C. in under an hour, and is finding many applications in high temperature brazing and modern metallurgical processes.

RADIANT HEATING.

The reflector panel heater shown in fig. 76 is a new item in the radiant heating field and is being used extensively in the textile and allied industries. It consists essentially of sheathed wire elements backed by a reflecting sheet of aluminium, but the

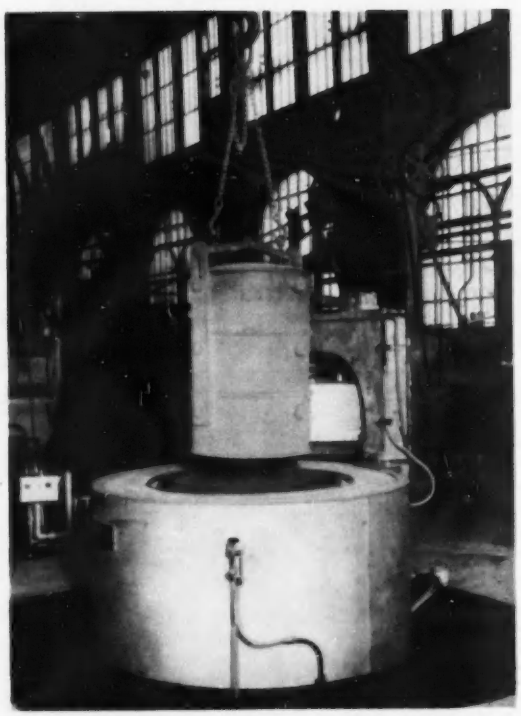


Fig. 74.—Gas-carburising furnace at Vickers Armstrong Ltd., Newcastle.

elements are placed with their length at an angle to the direction of travel of the material. This gives even heating across the width and avoids any possibility of "streakiness." To offset the cooling effect at the edges caused by draughts and the supporting framework, the outer elements are arranged to have a higher voltage than the remainder, and in addition are sometimes spaced closer together. Panels are normally made in sizes designed to cover the standard widths of fabrics, but any desired size can be obtained.

Heaters of this type have been supplied to manufacturers both in the United Kingdom and overseas, for such processes as nylon setting, gelling P.V.C. paste in the production of waterproof fabrics, and in the manufacture of conveyor belts for coal mines and for the evaporation of moisture from the rubber latex under-surface of needleloom carpeting.

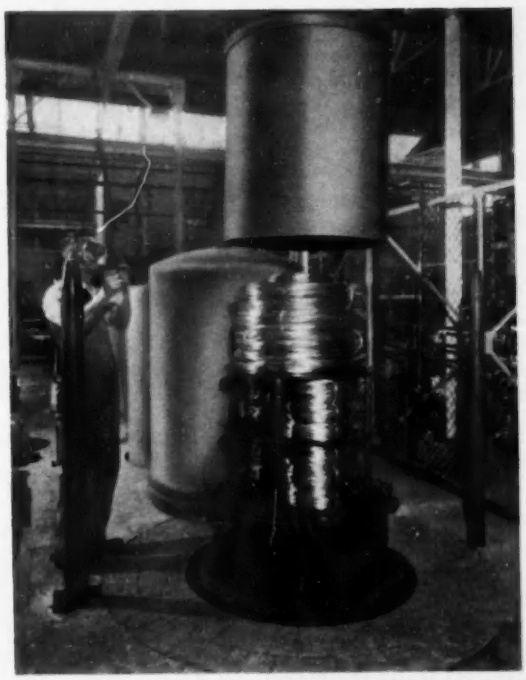


Fig. 75.—75 kW furnace at Pirelli-General Cable Works Ltd., Eastleigh.

The use of radiant heat to accelerate the drying of cellulose finishing lacquers on radio and television receiver cabinets has been mentioned before*. Now the woodfiller coat, which was previously air-dried overnight, is being force-dried by the same method. This is an important development in view of the large increase in output and the necessity for economy in floor space. The oven supplied for this process is 32 ft. long, has an operating loading of 56 kW, and will handle 3,000 to 6,000 cabinets per forty-hour week, depending on their size.

* *G.E.C. Journal*, Vol. XXI, No. 1, p. 42, January, 1954.

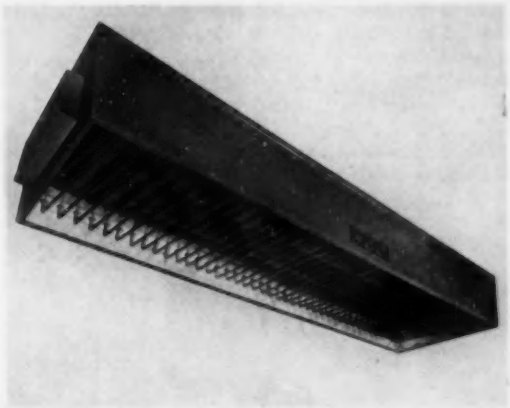


Fig. 76.—This reflector panel radiant heating unit is in wide use in the textile industry.

As is well known, one of the main applications of radiant heating is in paint stoving, and in a recent installation for this purpose two ovens are situated on the same conveyor line. They stove the prime and finish coats on refrigerator components such as doors, hinges and channel sections. Both ovens are of the sheathed wire element type and the heat is controlled by energy regulators.

WELDING.

A hand-welding attachment (fig. 77) has been developed for use with the Type PH6084 spot welder. The two welding electrodes, mounted side by side, are connected to the secondary of the welding transformer via resilient cantilevers and heavy-duty flexible leads. The resilient mounting of the electrodes ensures an even distribution of pressure despite any irregularities in the surface of the material.

Fig. 77.—Hand-welding attachment for use with G.E.C. spot welder.

With this device, welds may be made where only one side of the sheets to be welded is accessible. Two welds are made simultaneously, the welding current passing from one electrode to the upper face of the work, then through both top and bottom sheets and returning via the other electrode.

This equipment has been used in the manufacture of thermal insulators and radio valve components, but its main application has been in the construction of blankets for jet engines, where the inner and outer stainless steel sheets are separated by insulating material.

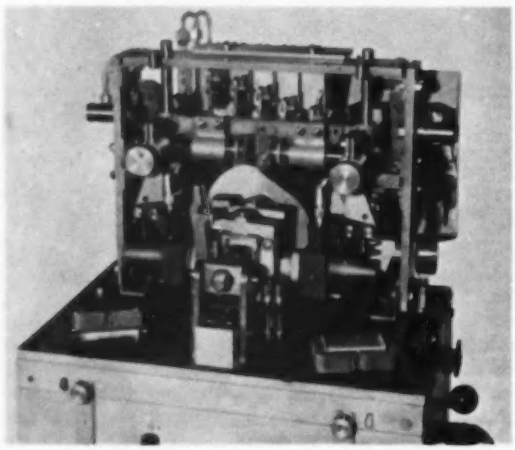


Fig. 78.—Choke welding machine using "Twin-Argon" process.

The G.E.C. "Twin-Argon" welding process* has been used in the manufacture of chokes for fluorescent lighting components. The choke is set in position for welding by the clamps, which are operated pneumatically; the operator then sets the air gap of the choke and measures its characteristics against a standard, adding or removing laminations as necessary. Once the correct characteristics are obtained, the specially notched edges of the laminations are fusion welded to keep them in the correct position. A front view of the machine with its protective screen removed is given in fig. 78. The welding torches, mounted on each side of the choke, make both welds simultaneously by a downward movement.

The "Twin-Argon" polyphase arc lends itself well to the mechanisation of welding processes, the very stable arc being little affected by imperfections in the electrical connections of individual stampings or by the oxide coatings present on the surface of the material.

AGRICULTURAL HEATING.

Combine harvesting is now widely practised in Britain for grain crops, and suitable equipment for drying and storing is frequently required. A wide variety of driers is available, ranging in capacity from two tons per day to two tons per hour or more, but most of these plants are used during a comparatively short season; their value to the farmer can be greatly increased if their use can be extended to other crops such as wilted grass, lucerne and legumes.

The G.E.C., which for some years has been supplying electric platform driers for dealing with grain in

* *British Welding Journal*, Vol. 1, No. 9, pp. 403-408, September, 1954.

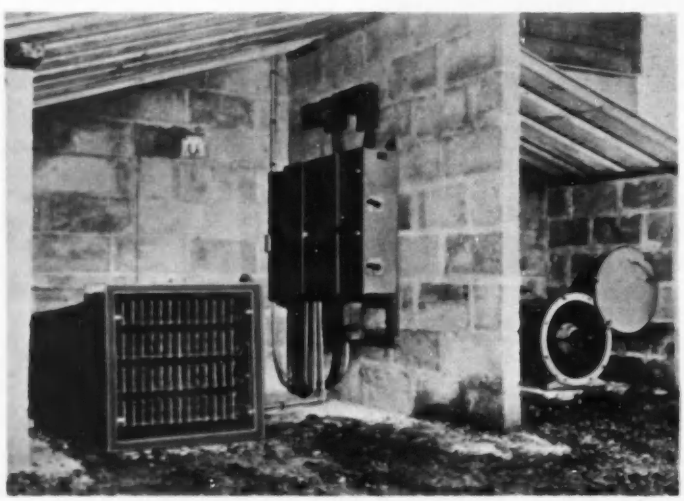


Fig. 79.—Multi-purpose crop drier.

sacks, has now introduced a multi-purpose crop drier (fig. 79), developed from the work of the Electrical Research Association. The equipment is based generally on the Transverco sack platform, but in some installations sacks of grain are assembled in the form of a tunnel through which warm air is blown, green crops being placed over a skeleton duct or on a false floor.

Before being taken to the drier, the green crop is wilted in the field, to reduce its moisture content to about 60 per cent. During the first process in the drier a comparatively large volume of cold air is used, and later the volume of air is reduced and its temperature raised. The equipment includes a duct air heater, control panel and Aerofoil fans with baffle plates to reduce the volume of air for the second stage for green crops and also when drying grain.

PLANT IRRADIATOR.

A new plant irradiator has been developed which gives a greater coverage of plants, so reducing the cost of an installation. A 400 W Osram mercury lamp is used, with a reflector of super-purity aluminium. The use of irradiators to increase the early yield of tomatoes and cucumbers is well known, and they have also been used to control the growth of plants in commercial and research establishments.

Another new appliance for horticultural use is the inexpensive greenhouse heater shown in fig. 80. This has a loading of 750 W or 1,500 W, is compact and is fitted with a sheathed-wire element. It also has a water trough to enable the atmospheric humidity to be raised.

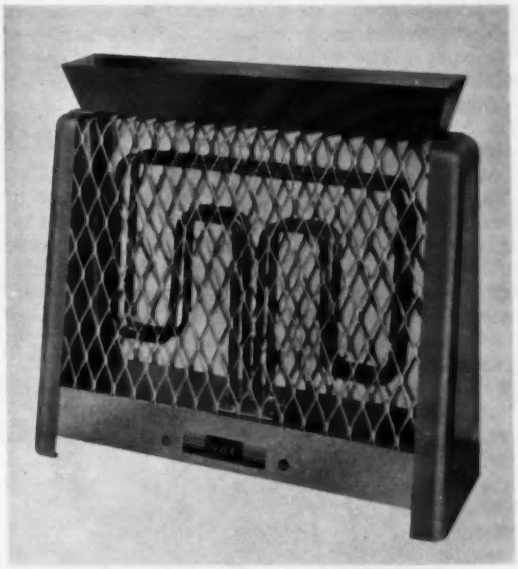


Fig. 80.—Greenhouse heater with water trough.

Instruments

Recent developments in laboratory indicating instruments include the production of 12 in. laboratory standards (fig. 81) of very high quality. Several types of these instruments are now available, all in either single- or multi-range form and incorporating several interesting features.

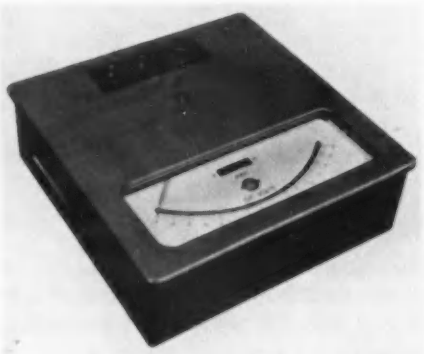


Fig. 81.—12 in. laboratory standard voltmeter.

The movements are almost totally enclosed in screening cases to protect them against stray magnetic fields. Resistances and similar parts are freely ventilated, and contained in compartments separate from the movement in order to reduce self-heating to a minimum. Levelling devices are fixed to the instrument cases, and spirit levels are also provided. The thermometer inside the case is visible to the operator through a magnifier and an aperture in the scale. The 12 in. scales are finely divided, a vernier type of marking allowing high accuracy in reading. Depending on the type of movement used and other factors, the accuracy lies between 0·1 per cent. and 0·5 per cent. of the full-scale value.

Equipment is now available for the summation and indication of the total generator load of a power station or similar source of supply. The apparatus has two main parts : The transmitter (fig. 82) consists of an induction wattmeter movement, which is made to suit the circuit to be measured (e.g. single-phase, three-phase balanced or unbalanced load) and is coupled to a moving coil relay fitted with maximum and minimum contacts. The indicator, usually showing generator total load, can be up to 30-40 in. in diameter, and may have either a single- or double-sided scale, and be illuminated. A further indicator or indicators can be used with the transmitter for use in the control room or other convenient location.

A range of small-current transformers, suitable for use with standard ironclad switchgear and $\frac{3}{4}$ in. diameter busbars, is being developed to cover ratios from 100-600 to 5 amp. The maximum diameter is $2\frac{1}{2}$ in. in the 100-300 amp. range and $2\frac{3}{4}$ in. for the remainder of the range.

Accelerometers and strain gauges using the piezo-electric properties of barium titanate have been developed. This material has advantages over quartz in that it is cheaper and has a higher electromechanical coupling with a much lower output impedance. The accelerometers (fig. 83) are simple devices, consisting of a barium titanate element soldered between two brass pieces. These devices are used to measure transient accelerations up to 1,000g at frequencies between 20 c/s and 20 kc/s. The strain gauges, also known as vibration pick-ups, consist of thin rectangular plates of barium titanate and can be used either to detect or to excite vibrations. This latter property is of considerable advantage in many applications. The excitation frequency can be varied over a wide range, and mechanical resonances are then observed on an

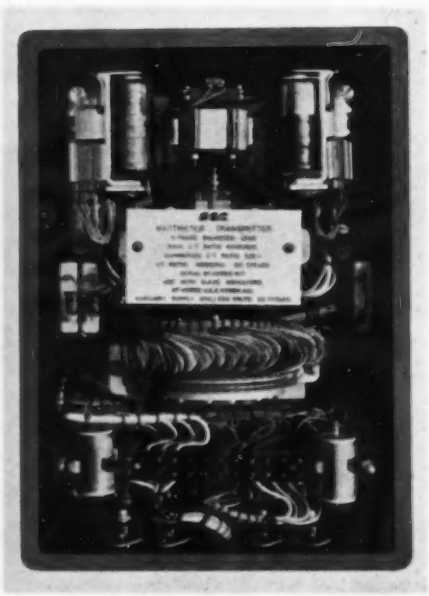


Fig. 82.—Transmitter for summation and indication of generator total load.

indicating gauge. The main value of these devices has so far been in turbine research, where they offer far greater sensitivity than resistance strain gauges.

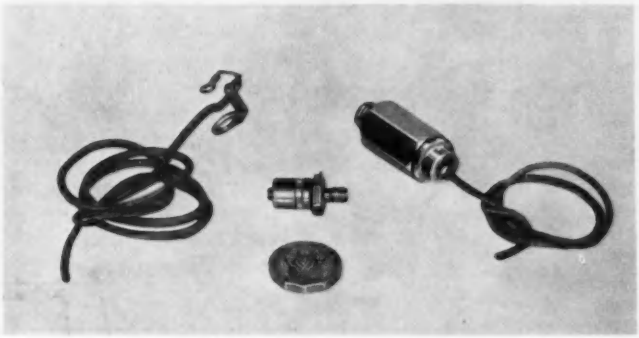


Fig. 83.—Barium titanate accelerometer.

The electromechanical transducer system, mentioned previously*, has proved particularly applicable to the measurement of turbine expansion characteristics. It can be used to measure both the absolute longitudinal expansion of the turbine casing and, where applicable, the differential axial expansion of the shaft in relation to the casing. When used together with a recorder, the transducer system provides a valuable record of the expansion characteristics of a turbine during, for example, its running-up period, and may even enable this period to be reduced. The recorder/controller or indicating instrument can be fitted directly into the control panel normally associated with any turbine installation. A close-up view of a typical set-up, using two transducers for measurements on a 30 MW turbo-generator set, is shown in fig. 84. The transducers are available for a variety of different ranges, and enable readings to be taken to within an accuracy of 1 per cent. of the full-scale reading. Mechanical displacements of less than 0·001 in. can be measured directly in this way, and no thermionic valves, barreters or other electronic devices are used. The equipment requires virtually no maintenance, and is able to withstand heavy usage.

* *G.E.C. Journal*, Vol. XIX, No. 1, pp. 67-68, January, 1952 and Vol. 22, No. 1, p. 46, January, 1955.

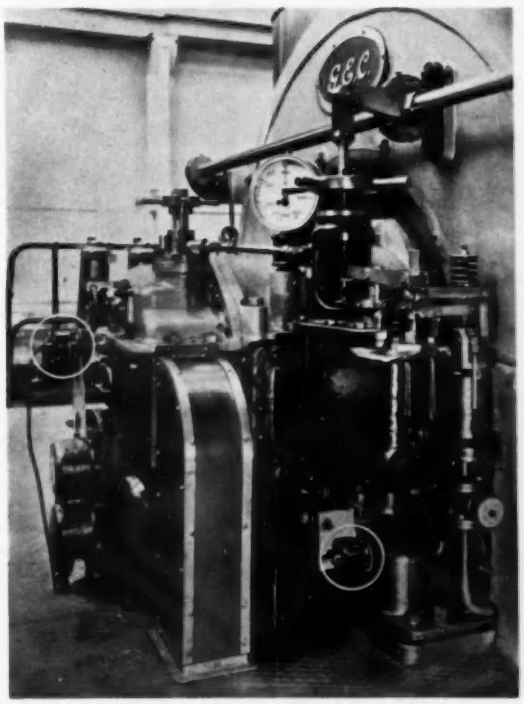


Fig. 84.—Close-up view of the end of a 30 MW turbo-generator, showing two transducer measuring heads (circled) in position.

Three instruments developed primarily for use in experimental work in the Research Laboratories are of interest. The first is an instrument with good stability which provides a quick and easy method of measuring the conductance of circuits and components having comparatively low losses at very high frequencies. Effective parallel resistances of the order of 10KΩ to 0·5MΩ can be measured. The main use of this instrument has been the comparison of losses in nominally identical circuits. It is possible to repeat measurements of components and circuits to within an accuracy of 0·5μmhos in losses up to 100μmhos.

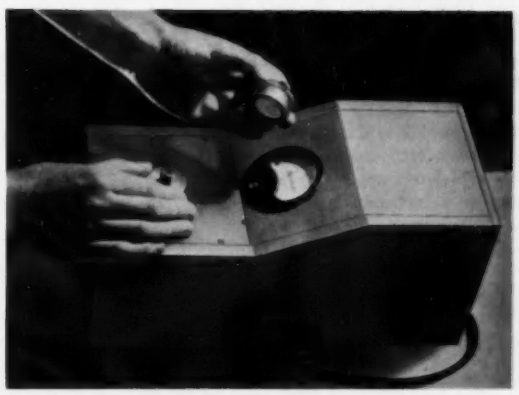


Fig. 85.—Photometer for assessing the relative luminances of fluorescent powders.

A direct-reading photoelectric differential colorimeter has been constructed in experimental form and

used for the routine measurement of the chromaticity of cathode-ray tube screens and fluorescent tubes. A selenium photovoltaic cell is used in conjunction with three Dufay-Chromex filters, so designed as to give overall spectral sensitivities approximating to the C.I.E. $\bar{x}$, $\bar{y}$ and $\bar{z}$ distribution functions. The colorimeter is in two sections, as shown in fig. 86. One compartment houses the photocell and a wheel carrying the three filters. The wheel can be rotated to bring each filter in turn to a position in front of the photocell, which can view the light source under test through a circular aperture in the side of the box. The second compartment contains the equipment for measuring the photocell current and for determining the chromaticity of the source under test.

Fig. 86.—Direct-reading photoelectric differential colorimeter.

Lastly, a simple photometer has been developed to measure the comparative luminances of fluorescent powders. It consists essentially of a cubical box with a totally black inner surface and a small circular hole in the centre of the hinged lid (fig. 85). Short-wave u.v. radiation is provided by a low-pressure mercury vapour discharge in a circular quartz tube, which also surrounds a photocell. A standard circular cell with a quartz window, holding about 5g. of phosphor, is placed in the upper hole in the photometer box and the luminance is measured in terms of the photocell current. For rapid comparison of luminances, two such cells are used, one filled with the powder under test and the other with a standard phosphor of the same colour, type and general composition.

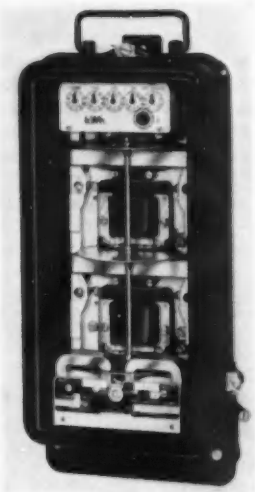


Fig. 87.—Type KT4 polyphase meter with built-in torque balancing system.

POLYPHASE METERS.

The Chamberlain & Hookham K type meter element, which is now well established, has been extended during the past year to include two- and three-element polyphase meters, types KT and KT4. A novel torque balancing arrangement has been built into each element so that variation of torque does not interfere with the calibration of the meter (fig. 87).

Lamps and Lighting

LIGHT SOURCES.

FLUORESCENT TUBES.

Following the improvements in efficiency of Osram Natural and Deluxe Warm White tubes mentioned in last year's Progress article*, increased efficiencies for Daylight and Colour Matching tubes came into effect recently. The present figures are given in the table below :

Efficiency (lm./W)

Colour	80 watts		40 watts	
	Initial 100 hr.	Average thro' 5,000 hr.	Initial 100 hr.	Average thro' 5,000 hr.
Natural	46	39	48	41
Deluxe Warm White	40	32	42	34
Colour Matching	44	38	46	40
Daylight	55	49	57	51

MERCURY AND SODIUM LAMPS.

The range of colour-corrected Osram mercury fluorescent lamps has been extended by the introduction of a 250 W type. The improved colour of these lamps has simplified the problem of street lighting near railways, where directional shielding has often been necessary to avoid confusion with green signal lights. The increased proportion of red in the colour-corrected lamp modifies its appearance to give a whitish light not so readily confused with signals.

Sodium lamps maintain their popularity for street lighting. The Osram " integral type " lamp, developed at the Research Laboratories and mentioned briefly last year, in which the discharge tube and outer jacket are sealed together as a single unit, is undergoing large-scale tests under street lighting conditions. In the integral lamp, radiation shields for each limb of the arc tube reduce heat losses; this in turn has permitted an increase in the arc tube diameter, giving a lower value of current density with a resultant improvement in efficiency of about 10 per cent. This important new design (fig. 88) also has the advantages of improved lumen maintenance and a reduced tendency for the starting voltage to rise during life. The same wattage ratings as those at present in use have been developed, and the dimensions and electrical characteristics of the new lamps ensure full interchangeability with existing lamps.

Development work on new glasses for sodium discharge tubes has resulted in a glass which remains substantially free from discoloration even after 4,000 hours of lamp life. Problems still remain to be resolved with the new glass which, in due course, should contribute markedly to the steadily improving performance of sodium lamps.

TUNGSTEN FILAMENT LAMPS.

Although the basic design of filament lamps has changed little over many years, improvements in construction are made from time to time. In the past year the design of filament support wires has been changed from the well-known 3-support system to a 2-support pendant arrangement (fig. 89). This affects the Osram 40 W, 60 W, 75 W and 100 W high-voltage coiled-coil lamps, and results in an improvement in efficiency as well as enabling the lamps to give full performance in all burning positions.

Many types of filament lamps are subjected to shock and vibration in normal service, notably those used in trains, ships, aircraft and motor vehicles ; the changing design of equipment for almost all forms of transport imposes new and often more arduous conditions. Studies of these conditions, and re-examina-

G.E.C. Journal, Vol. 22, No. 1, p. 48, February, 1955.

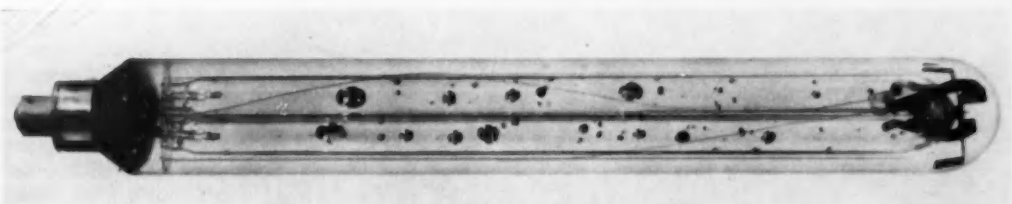


Fig. 88.—The new Osram " integral type " sodium lamp.

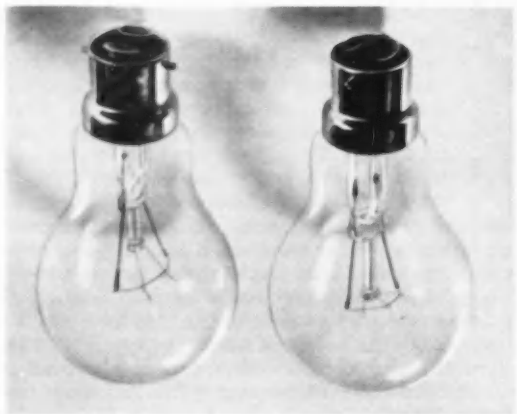


Fig. 89.—The 2-support and 3-support pendant arrangements for tungsten lamp filaments.

tion of the basis of design and testing of certain lamps, have resulted in improved resistance to vibration in several types.

The range of Osram reflector spotlights has been extended by the introduction of a 100 W type. These lamps have integral, internally aluminised reflectors and provide a convenient method of obtaining a concentrated beam of light.

General lighting service lamps will be required to conform to an amended British Standard Specification.

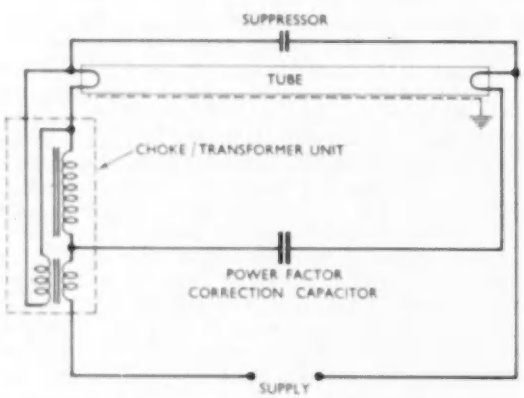


Fig. 90.—Circuit diagram of new instant start gear for fluorescent tubes.

Among its important features are more stringent requirements for initial wattage dissipation and luminous flux, and revised clauses on lumen maintenance and lamp life.

Electroluminescence.

There has been continued progress in the understanding of the mechanism of this new phenomenon. Luminous efficiencies of practical devices remain low but improvements in the phosphors and the methods of manufacturing the panels have resulted in better performance.

Phosphors.

The quality of phosphors for fluorescent tubes has improved steadily, particularly phosphors of the halophosphate type. The increase in initial efficiency has been accompanied by a corresponding improvement in lumen maintenance throughout tube life.

Among new phosphors which have been investigated is a range of tin-activated alkaline earth phosphates, which give a wide range of colours including blue, green, white and red.

Discharge Lamp Auxiliary Gear.

A new and cheaper type of instant start gear for 5 ft. 80 W and 4 ft. 40 W fluorescent tubes has been developed which is expected to result in greatly increased use of this type of circuit. In the new design, one cathode is preheated by a current transformer, the primary of which is in series with the choke, both being wound on the same core. The other cathode derives its preheating current through the shunt capacitor provided for power factor correction (fig. 90). This arrangement achieves economy in copper and laminations. A similar type of gear for operating the 8 ft. 125 W tube on phase-to-phase supplies of about 400 volts has also been designed, as well as instant start gear using a voltage pulse technique for 80 W and 40 W tubes.

Improved gear for cold cathode fluorescent tubes, high pressure mercury vapour lamps and sodium lamps has reached an advanced stage in design, and particular progress has been made in the design of equipment for starting and operating mercury lamps at the low winter temperatures encountered in some parts of the world.

New types of capacitors for discharge lamp circuits using a liquid impregnant and having improved reliability and life have been introduced. These use an aluminium container of a convenient oval shape.

Electronic control equipment for dimming both hot and cold cathode tubes, of simplified design and capable of handling increased loads, has been developed, and is now in regular commercial use.

ILLUMINATION.

Interior Lighting.

In last year's Progress article* it was reported that experimental combinations of tungsten lamps and the new Osram 80 W and 125 W mercury fluorescent lamps showed that the good colour rendering obtained might be applicable in industry and even in commerce. This combination of light sources has now been

* *G.E.C. Journal*, Vol. 22, No. 1, p. 54, February, 1955.

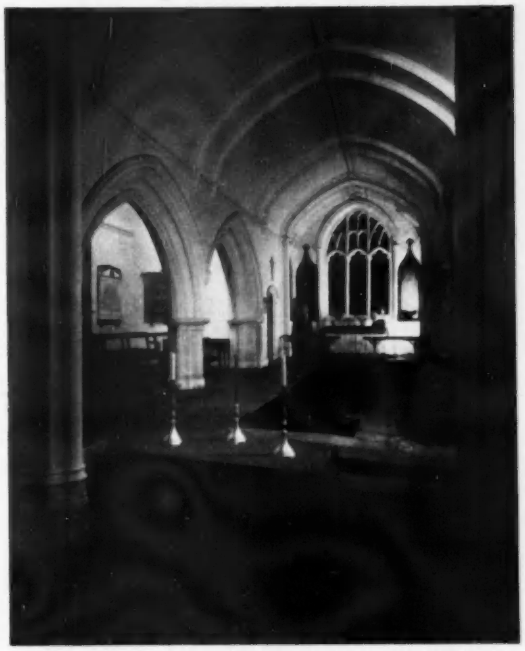


Fig. 91.—Lighting in Hexton Parish Church, Hitchin.

applied to shop window lighting with striking results. Not only is the colour rendering excellent but the display has attractive sparkle and good modelling. The efficiency of the system is good, and it is possible to achieve very high illuminations. In an experimental window at the Research Laboratories well over 1,000 lumens per square foot was obtained.

Studies have continued of ceilings which combine lighting with heating and sound proofing. In particular, experiments have been made on suitable ceiling contours which will direct the light in a manner appropriate to the work being undertaken in the interior, and which will also achieve a ceiling brightness conforming to the brightness pattern of the remainder of the interior.

Further experience has been gained on Designed Appearance lighting schemes. Several of these have been prepared, including some for large new buildings, with the enthusiastic co-operation of the architects concerned. The value of being able to estimate the appearance of the interior more accurately than hitherto is becoming increasingly evident, and the principles involved have been described in a paper to the C.I.E. at Zurich.

Three indoor lawn tennis courts at Queens Club, London, have been lit by fluorescent tubes in angle reflectors. Each court has 40 twin-light fittings with two 80 W tubes mounted in continuous lines on each side, with strongly made louvres fitted to limit the side spread. First-class playing conditions are achieved in these, the first indoor courts in the country to be lit in this way.

Fig. 91 shows the lighting at Hexton Parish Church, Hitchin, Hertfordshire. This installation is a particularly interesting example of the deliberate use of light and shade to enhance the beauty of the architectural forms. There is a coherent flow of light across the church and chancel, with most of the fittings on the south side directing their light northwards; and the altar is lit by a single vertical fluorescent tube on the south side of the sanctuary. The brightness of the chancel arch, as seen from the nave, is considerably greater on the north side than on the south, making a point of special interest.

Exterior Lighting.

Considerable research has been carried out on the lighting of tree-lined roads. In the course of the experiments typical suburban roads were lit with the aid of portable lamp standards offering mounting heights ranging between 5 ft. and 15 ft., and using fittings with a variety of light distributions (fig. 92). A preferred distribution was devised, providing reasonable illumination on pavements, gardens and

Fig. 92.—Experimental lighting on a tree-lined side road.

Fig. 93.—Side road lanterns with injection moulded "Diakon" refractor bowl, for incandescent lamps.

house fronts as well as on the road surfaces, and lanterns giving this distribution were compared with those commonly found in side street installations. It is believed that the new distribution will play a useful part in the practical lighting of tree-lined side roads.

Among the most interesting developments in street lantern design have been those making use of the injection moulding of "Diakon". After many experiments with the moulding technique two new injection-moulded optikons for side road lighting have been introduced.

The first (fig. 93) which is suitable for use with incandescent lamps of up to 150 W, is the first plastic, one-piece refractor bowl to be produced controlling light in the horizontal and vertical planes. It has vertical prisms on the outside and horizontal prisms inside, an arrangement which enables the optikon to be cleaned by rain-water. The other (fig. 94) is for sodium lighting, and has the refractor plates recessed on the inside of the bowl. Injection moulding has many advantages over other methods of manufacture in that it provides a very high degree of repetitional accuracy, more efficient light control, greater impact resistance and light weight.

Two new hot-cathode fluorescent lanterns have been designed, of which one is the Vertical Four-Eighty shown in fig. 95. This is a post-top lantern which carries the four 80 W fluorescent tubes in a "Perspex" opal cylinder, with top and bottom copper spinnings and a spun finial making the lantern totally enclosed and weatherproof. Tube operating gear is housed in the bottom spinning.

The new Four-Forty lantern is somewhat similar to the Vertical Four-Eighty, but the "Perspex"

Fig. 94.—Sodium side road lantern with "Diakon" refractor bowl for sodium lamps.

cylinder is tapered. It is suitable for four 2 ft. 20 W or 40 W fluorescent tubes and is designed primarily for side roads, though its pleasing appearance suggests numerous other applications in decorative lighting. The tube operating gear must be housed outside the lantern.

A permanent installation of decorative street lighting is being erected along the entire length of the promenade at Blackpool, the Lancashire resort famous for its annual illuminations. In connection with this scheme,

Fig. 95.—Vertical Four-Eighty lantern.

the G.E.C. was asked to design a lantern suitable for use with eight 2 ft. 40 W fluorescent tubes. As a result, an order was placed with the Company for 564 lanterns, which are again of the tapered "Perspex"

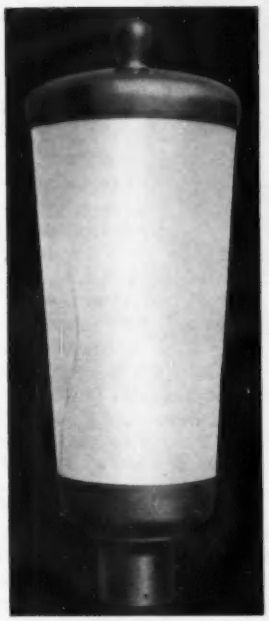


Fig. 96.—"Blackpool" lantern, designed for permanent installation along the promenade of this famous resort.

Fig. 98.—Floodlighting of the London Terminal Building of B.O.A.C.

cylinder type with top and bottom copper spinnings. The approved design shown in fig. 96.

It is appropriate in this air age that the Terminal Building of British Overseas Airways Corporation should be one of London's landmarks, and the recently completed G.E.C. coloured floodlighting scheme makes it as outstanding by night as by day (fig. 98). The façade, which curves slightly from a

Fig. 97.—Floodlighting of Rosenborg Castle and arena for the military tattoo during the British Trade Fair in Copenhagen.

Fig. 99.—Measuring the reflection characteristics of turf.

180 ft. high central tower, has an overall spread of 200 ft. Red floodlighting is used at the extremities, changing to white at the centre and including the front face of the tower.

The back face of the tower also has white floodlighting, but the sides have a mixture of sodium and neon, giving a golden colour changing to red at the bottom. Additional narrow beam floodlights are trained on to the clock faces, and the flag has its own lighting provided by four 1,000 W floodlights situated on top of the tower.

In contrast with the modernity of this building is the early seventeenth-century Rosenborg Castle in Copenhagen, which was floodlit in connection with the military tattoo held in the Rosenborg arena during the British Trade Fair in the city. The castle is constructed

Fig. 100.—Floodlighting at Wembley Stadium.

of red brick and has an attractive verdegris-covered copper roof. The main floodlighting was by red neon lights supplemented by sodium units picking out the white paintwork. The colour of the roof was brought out at night by blue fluorescent tubes mounted along the guttering, and additional tungsten floodlights were focused on the tops of the rear towers visible to spectators in the arena stands (fig. 97).

The principles of floodlighting major football fields from high towers are now well established, but special problems are encountered in lighting the smaller fields where it is essential to keep the capital cost very low. During the year experimental work has been undertaken to devise the simplest system of lighting for small grounds. The work included studies of the reflection characteristics of turf in some of its varying conditions (fig. 99).

The largest permanent arena floodlighting system in this country has been installed at Wembley Stadium. It consists of 192 floodlights mounted 100 ft. above the ground in groups of 24 on 8 towers. All groups combine to use 340·4 kW of lighting load. To ensure the maximum of illumination and the minimum of glare, the installation comprises a combination of four optical systems (fig. 100).

Aerodrome Lighting.

On many airfields an angle-of-approach indicator is used to assist the pilot in judging his glide path just before touching down. Three contiguous beams are projected, red, amber and green, any of which the pilot may see according to whether he is too low, too high, or on the correct path. Although such devices have proved useful, their value has been limited by the low intensities of the beams.

Now a more powerful light has been designed and tested in prototype form, giving intensities at least 50 times as great as conventional units. Among the many problems that had to be solved were the prevention of overheating of the colour slides, finding colours readily distinguishable from one another, and ensuring a sharp transition from one colour to the next. Flight tests gave very hopeful results, and two prototypes are being given extended trials.

The use of lightweight equipment for aerodromes continues to grow. A new low-intensity, one-piece refractor for runway lighting accommodates lamps up to 100 W and gives a symmetric distribution. It can also be provided with a green glass for use as a threshold light.

Studio Lighting.

Among the principal advances in the studio lighting field are three new items of G.E.C. equipment for use in the television industry.

Fig. 101.—Studio scoop, for use with a 500/1,000 W lamp.

The studio scoop shown in fig. 101 is for use with one 500/1,000 W. G.L.S. lamp and has an aluminium body formed from an 18 in. dia. elliptical spinning. The reflector may be locked in any desired degree of tilt, and a heat-insulated lifting handle is also provided.

A floodlight has been designed to house six 100 W lamps in two banks of three. Each bank is masked by a movable, white opal " Perspex " cover.

A new 2 kW spotlight has the advantages of light weight (just under 25 lb.), a simplified clamp for tilt adjustment and an improved form of focusing which facilitates rapid adjustment.

Telecommunications

ELECTRONIC SWITCHING.

The development of equipment for all aspects of electronic switching is making good progress, and prototype apparatus is being constructed. A prototype electronic keysender, whereby an operator can set up calls much more quickly than by using the normal dial, is undergoing field trial in an exchange. The apparatus is assembled on leaves, hinged on a base plate which fits into a panel. Connections to the outside wiring are made by means of multi-way plugs. When the plugs are removed the assembly can be slid out of the panel, and the leaves opened on their hinges (fig. 103) to give easy access for maintenance.

Fig. 102.—Test desk and main distribution frame at Kuching exchange.

The electronic register mentioned in a previous review of progress* has been redesigned to meet more complex requirements, and a prototype of the new equipment will be completed in the near future and submitted to field trial. There will also be early completion of electronic telemetering equipment for the transmission and display of meter readings over a distance. This equipment uses the high speed of electronic operation to "look" in quick succession at values, such as load at a substation, and to transmit corresponding signals to produce meter-reading displays at a control station.

The CCT6 (cold cathode triode), which is used extensively in the above equipment, is in production on a fairly large scale, and very good results are being obtained. Some of these tubes have been undergoing an extensive life test in a laboratory model of the telemetering equipment and have now completed about two years of continuous test without tube failure. During this test, many of the tubes have completed over 1,000 million cycles of operations.

TELEPHONES.

A new telephone exchange, which opened during the year at Kuching in Sarawak, introduced the SE50 two-motion selector to South-East Asia. The exchange (fig. 102) is equipped for 800 subscribers' lines, and provision is made for ultimate extension to 2,000 lines. Access to other exchanges in the area is obtained via a two-position manual switchboard.

In a new exchange being installed at Humboldt, in Canada, the SE50 is used as a line-finder as well as for the later switching stages. The exchange is equipped to work into the national dialling scheme which, it is envisaged, will extend over both Canada and the United States.

* *G.E.C. Journal*, Vol. 22, No. 1, p. 56, February, 1955.

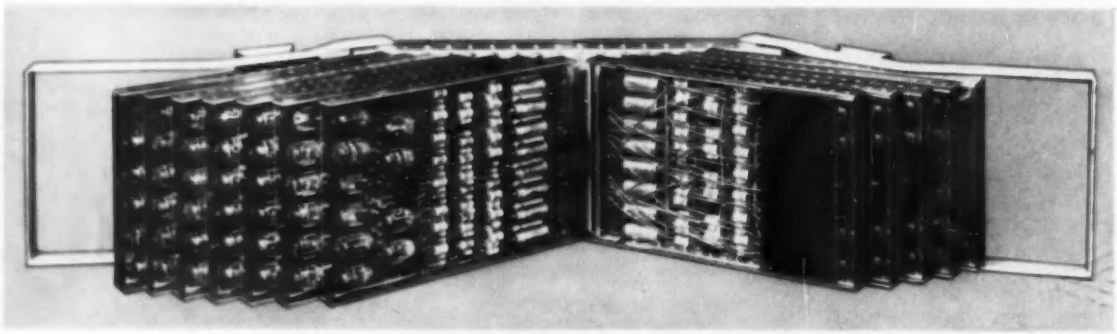


Fig. 103.—Electronic keysender assembly removed from panel for maintenance.

Work is progressing on the contract to supply telephone exchanges and transmission equipment for a comprehensive communication network in Haiti. Surveys have been completed on the island, and cable laying is well under way (fig. 104).

A new design of power plant is now in production for use in small and medium-size telephone exchanges where the total busy-hour load does not exceed 200 amp. The equipment is contained in self-supporting sheet-steel cubicles finished in light-grey enamel. The appearance of the equipment presents a marked contrast to the previous plant of the motor-generator type. The new design is made possible by the increasing availability of efficient and reliable rectifiers for battery chargers, and compared with former equipment it occupies less space, is easier to install and the cubicles are self-supporting.

A new loudspeaking telephone for private exchange systems is now being manufactured. The telephone consists of two units, a desk unit containing the microphone and loudspeaker, and an amplifier unit which may be installed elsewhere in the room, or in an adjoining room. The two parties to a conversation may each use a loudspeaker because voice-operated switching gives undistorted conversation on a 2-wire circuit without the need for a manual " talk/listen " changeover switch.

A conventional handset is provided for use when the user does not wish other people in the room to listen to the incoming speech. A master instrument can also be supplied, which incorporates additional facilities to permit the user to call up to a maximum of twenty numbers on the exchange by the simple operation of a key. Other numbers on the exchange can be called in the normal way.

LOADING COILS.

To improve the transmission efficiency of telephone lines, inductances of specific values may be inserted at regular intervals. A reduction in the size of individual coils has now made it possible to reduce the size of conventional loading-coil cases for installation in manhole entry underground chambers. Individual coils have previously been supplied for insertion in joints where the number of pairs to be loaded has been four or less, and units of such coils can now be assembled to handle a maximum of 104 pairs.

LINE COMMUNICATIONS.

The expansion of television services in the United Kingdom has called for special types of equipment. Among these are wide-band amplifiers for transmitting programmes over co-axial cables between Birmingham and Manchester, with an extension to the Independent Television Authority's transmitter near Bolton; and between Museum Exchange in London and the B.B.C. Crystal Palace transmitter. At the terminations of these cables a television translating equipment is fitted, which converts the picture signal to a form suitable for cable transmission and vice-versa.

RADIO COMMUNICATIONS.

Radio frequently provides a satisfactory—and sometimes preferable—alternative to line systems, and during the past year several radio links for television operating in the 2,000 Mc/s band have been provided.

The British Post Office has ordered links for setting up the I.T.A. services and for extending those of the B.B.C. One of these links provides two channels from Birmingham to Lichfield and one channel in the reverse direction. Another two-channel link extends the B.B.C. Television Service to the Norwich area, and links for other areas are in course of manufacture.

Another interesting contract was that for providing a two-channel television link in Canada between the towns of London and Windsor, a distance of 120 miles, requiring four relay stations. Contactless switches for reversing the direction of the link are a special feature of this system ; they are incorporated in the aerial feeders and are remotely controlled.

The television link system for Switzerland, supplied by the G.E.C. in 1954, has been extended by the provision of an east-to-west link between Uetliberg, near Zürich, and La Dôle, near Geneva.

For trunk telephone work the British Post Office has ordered a 240-circuit radio system operating in the 2,000 Mc/s band, for installation in Scotland. A simpler system, for conveying sixty telephone channels, has also been developed. A special feature of this system is its compactness, and although the performance is fully in accordance with C.C.I.F. requirements for international cable circuits, the complete terminal equipment (transmitter, receiver, power supplies and control circuits) occupies only one rack side.

Fig. 104.—Laying telephone cables in a street in Port au Prince, Haiti.

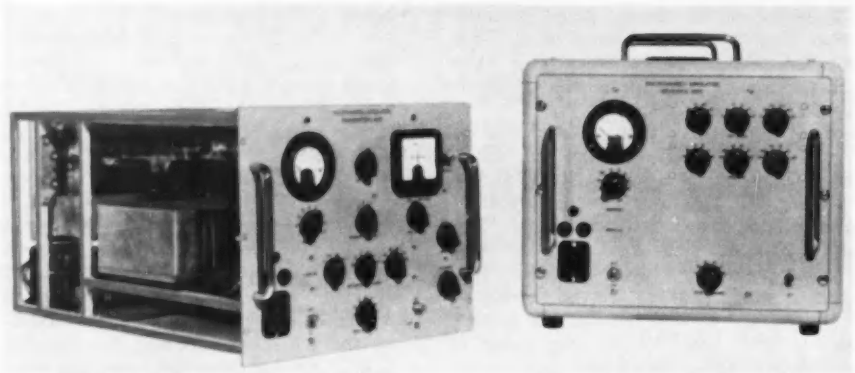


Fig. 105.—Multi-channel simulator for laboratory assessment of the performance of telephone links.

Much development work is being done on systems carrying very large numbers of telephone circuits to meet C.C.I.F. requirements and elaborate laboratory test equipment is needed to assess the performance of complete links or component parts. For example, fig. 105 shows a multi-channel simulator by means of which it is possible to reproduce artificially the effect of many hundreds of simultaneous telephone conversations.

SUPERVISORY CONTROL.

The supervisory control scheme for British Railways (Southern Region) is now partially in operation. The entire scheme comprises seventy-one rectifier sub-stations for feeding power to the tracks and seventy paralleling points, all normally unattended, together with five main feeding points from the grid, the whole to be controlled from three control rooms situated at Raynes Park, Lewisham and Selhurst.

A mimic diagram giving a geographical layout of the tracks and the E.H.T. network involved enables operations to be carried out at a control room by the means of small switches and push buttons. These are located on the diagram in the positions which correspond to those occupied by the circuit breakers on the actual layout. Fig. 106 shows the diagram and operator's desk for the control room at Raynes Park. Ultimately this board will control 527 circuit breakers, and 627 indications will be received. The entire system, when completed, will be the most extensive of its kind operated by British Railways.

CATHODE-RAY TUBES.

Investigations have been made with a view to improving the operation and cheapening the manufacture

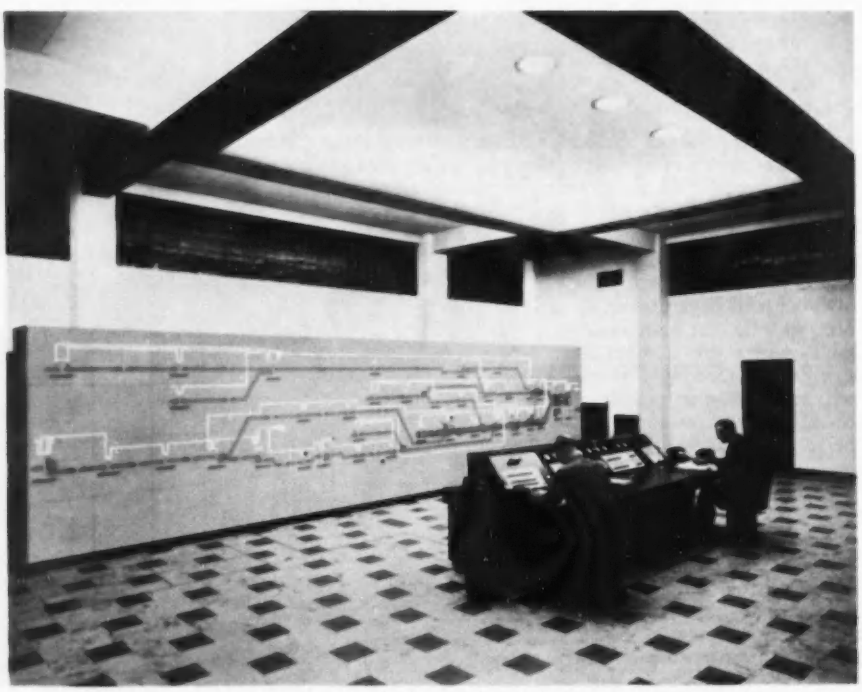


Fig. 106.—Mimic diagram and operator's desk at Raynes Park control room, British Railways.

of 14 in. and 17 in. aluminised television tubes. In this connection the screening and filming processes carried out before aluminising have been studied intensively, and one result has been a considerable improvement in the filming technique.

For non-aluminised tubes, processes have been developed whereby the screen is afforded complete protection against burn marks appearing during life due to screen charging. Measuring techniques and equipment for determining the screen potential have been greatly improved.

The new 21 in. tube has an aluminised screen and incorporates a new triode gun which gives a very narrow beam angle, suitable for wide scanning angles up to 90° and producing a high quality spot with a minimum of deflection defocusing.

Fig. 107.—12-watt high-quality amplifier (left) and transcription playing unit.

The trend towards larger sizes of tube has also entailed an increase in the operating potential applied to the final anode. To ensure satisfactory operation at these higher voltages (approximately 18 kV) the preparation, processing and assembly of the electrode systems have been investigated. The results of this work have been applied particularly to the zero-focus-voltage electrostatic gun.

The development and production of special instrument and oscillograph tubes has continued. These include various switch tubes, a multiplication tube and a new 9 in. diameter high-quality television monitor tube.

TELEVISION RECEIVERS.

The opening of the Independent Television Authority's service in London has resolved many problems in receiver design and technique, which previously could be planned only on theoretical and experimental grounds. Existing designs have now been proved basically sound. However, some changes have been introduced, mainly of benefit to the trade in that installation and servicing are facilitated. The most important change is the introduction of gang tuning over the Band I range. Subsidiary controls have also been made more accessible.

All receivers are available in both standard and fringe versions, the latter having increased sensitivity and fly-wheel time-base circuits to enable pictures to be obtained under the most adverse conditions ; and each model provides for reception on all Band I and Band III frequencies.

The range of table receivers with 14 in. and 17 in. tubes now includes a 14 in. type with front-mounted loudspeaker. Three console models are available, all with 17 in. tubes, the range including a new presentation of the contemporary style without doors.

RADIO BROADCAST RECEIVERS.

The inception of the V.H.F. F.M. service has provided a new element in broadcast radio, to cater for which three G.E.C. receivers—one table model and two radiograms—are available. The same basic chassis is used in each. This consists of an 8-valve receiver for reception not only of the new F.M. transmissions but also of the existing A.M. transmissions on the long and medium wavebands. A built-in frame aerial for long and medium wave broadcasts and an internal plate aerial for F.M. reception are provided, but an external broadcast aerial and a V.H.F. dipole can also be used if required. As accurate tuning is essential for satisfactory F.M. reception, a " magic eye " tuning indicator has been incorporated. The radiogram versions offer a choice of traditional or contemporary styling.

For the export market, two new releases are announced. One is a medium priced, multi-waveband, 5-valve receiver in Bakelite, with a wood veneered finish. The other is a small, two-colour Bakelite receiver, available in two versions for operation from A.C. mains or from all-dry batteries respectively.

SOUND EQUIPMENT.

A new 30-watt amplifier has been added to the range of G.E.C. sound equipment. It has an electrical specification similar to that of standard amplifiers produced in the past, but has been completely redesigned mechanically to simplify its construction, thus making for ease of service and routine maintenance. The new unit is for use as a basic amplifier in commercial public address systems. A new 50-watt amplifier of similar mechanical construction and general specification is also available.

For mobile use a 20-watt amplifier has been developed which operates either from a 12 volt battery or 100/250 volt A.C. mains. A noteworthy feature of the design is the avoidance of complicated switching between battery and mains working.

The application of the G.E.C. high-quality metal cone loudspeaker to public address systems is another interesting development in this field. For this purpose,

the loudspeaker is mounted in a small cabinet of about 1 cu. ft. capacity. The flat overall system which results from the use of this loudspeaker together with a ribbon microphone allows a high level of amplification without " ring-round " between microphone and loudspeaker —a point of great benefit in halls with poor acoustic properties.

A range of high-quality sound equipment has been introduced, of which the basic unit is a 12-watt amplifier specially designed for use with the metal cone loudspeaker for sound reproduction in the home. The instrument has a separate pre-amplifier unit, fitted with the necessary controls to enable quality to be adjusted to suit individual taste. The amplifier and pre-amplifier are mounted in a walnut veneered cabinet, with controls placed conveniently for armchair operation. A playing unit is obtainable, incorporating a transcription type gramophone, also mounted in a walnut veneered cabinet (fig. 107.)

A 25-watt amplifier, giving the same high quality of reproduction and facilities as the 12-watt unit, is also available, suitable for use in larger rooms or small halls.

An improved ribbon microphone of the high quality studio type has been put on the market (fig. 108). This has a very wide and level response, particularly good in the horizontal field, making it specially suitable for stereophonic recording. Another interesting item recently introduced is a wide range fader and mixer microphone input pre-amplifier, with a very low distortion factor and a frequency range which makes it suitable for high quality recording and reproduction.

Fig. 108.—Improved ribbon microphone for high-quality studio work.

VALVES.

A new development in transmitting valves for C.W. operation is a 500-watt tetrode (fig. 109). This valve has an efficiency of 55 per cent. at 500 Mc/s and 25 to 30 per cent. at 900 Mc/s, and should find application in transmitters such as would be used for Band V television.

A new type of receiving valve has been developed for use in the same frequency band. It is a low-noise, grounded-grid triode for use as a radio frequency amplifier at frequencies up to 1,000 Mc/s and incorporates a planar grid of very fine tungsten wires.

The production of this valve has been dependent on the development of special techniques for making the very fine tungsten wires. Moreover, a new type of grid-winding machine has had to be evolved for winding these wires at the accurately uniform spacing necessary for high performance.

SEMI-CONDUCTORS.

In spite of rapid development in junction diodes and triodes, the point contact types are still important. They have many and increasing uses, and their development continues.

Point contact germanium diodes, for instance, have been improved in temperature performance and can now be used at temperatures up to 70 deg. C. and stored at 100 deg. C. It has been found that germanium diodes can give an effective performance as mixers in U.H.F. television receivers (Bands IV and V), and this application is being explored.

In F.M. broadcast receivers, the functions of the detector and limiter circuits can be combined in a single circuit known as the ratio detector. Germanium point contact diodes work well in this circuit, and have the added advantage that their small size enables them to be placed inside the can of the final I.F. amplifier, thus reducing the possibility of stray pick-up. Complete details of a circuit using GEX34 diodes have been prepared.

Some development work has continued on point contact germanium triodes, since their performance in pulse circuits, such as are used in digital computors, is superior to that of existing junction types. Two specific types have been developed—a very close point spacing type EW51 and a wider spacing type EW61. The

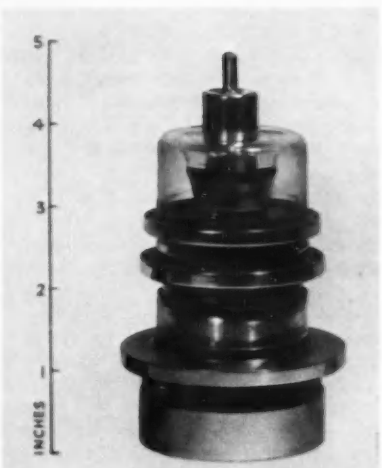


Fig. 109.—500W transmitting valve for C.W. operation.

former has a frequency cut-off of 4 Mc/s and the latter 1 Mc/s. The future of these types is however uncertain since it is possible that junction triodes, at present in development, may replace them in the majority of applications.

The performance of point contact transistors in high-frequency circuits has been studied, and in addition to work on oscillators and amplifiers at frequencies up to 10 Mc/s, several pulse circuits have been considered. The major field of application appears to be in digital computers. In this connection " shift-register " circuits, using EW51 transistors and operating at a digit rate of 300 kc/s, have been designed.

Further advances have been made in germanium alloy junction *p-n-p* triodes, and a family of low-power, low-frequency types has been developed. This includes the EW53, for general purpose use ; the EW58, for low-voltage applications in low-level audio amplifiers such as those used in hearing aids ; and the EW59, a high-voltage type most suitable for the higher output applications and for higher frequency operation as small signal amplifiers. Considerable progress has been made in improving the noise characteristics of junction triodes, and the EW58, for example, operating with an emitter current of $\frac{1}{2}$ mA, has a typical noise factor value below 10 db.

The factors limiting the high-frequency performance of junction transistors have been studied, and the results applied to improvements in design. Because of the large potential market for these devices in broadcast radio receivers, this investigation has been concerned mainly with performance in the R.F. and I.F. amplifier circuits involved.

In the point contact types the frequency limitation arises chiefly from the reduction of current gain with increasing frequency. In junction transistors the same applies but is seldom the principal frequency-limiting factor: it has been found that the product of collector barrier capacitance C_c and extrinsic base resistance r_{bc} has a major effect. Although types EW53, EW58 and EW59 were not designed for high-frequency operation, steps were taken to keep the product $C_c \times r_{bc}$ as low as possible, and this has been achieved particularly by the reduction of the base resistance to the unusually low value of 45 ohms. Comparatively high frequency operation is therefore possible.

Junction triodes suitable for operating at frequencies up to 10 Mc/s or more are also under development, and the complex design problems involved are being solved by the introduction of new techniques. These will be specially applicable to medium wave receivers.

In addition to work on high-frequency amplifiers, problems associated with automatic gain control and self-oscillating mixer circuits of radio receivers have been investigated. Some more general oscillator problems have also been considered and, in particular, new design techniques have been evolved for low-frequency resistance-capacitance oscillator circuits.

A new type of junction triode, EW57, is being developed for audio frequency amplification at medium powers. Two of these, with suitable cooling arrangements such as fins or direct connection to the chassis, and operated in a class B push-pull amplifier, are expected to give an output of 3 watts on a 24 volt D.C. supply. The results of studies of the factors causing distortion in transistor power amplifiers are being applied to the design of this triode.

A large number of circuits can be developed making use of the fact that the junction transistor can be operated as an almost perfect on-off switch. In particular, counter circuits, waveform generators (including time-base waveforms), relay controls and circuits, and multivibrators have been investigated, and in the case of multivibrators successful techniques have been developed for sharpening the output waveform. Another circuit, when coupled with a suitable rectifier of the same family, can be used to convert a small D.C. voltage to a higher value ; operating at efficiencies of 70 to 80 per cent., this has many applications including the provision of simple power supplies for Geiger counters.

The application of junction transistors to D.C. amplification has also been considered, and the types of circuit produced will be useful in the instrument field.

When the collector voltage of a junction transistor is made large it is possible for the current gain factor to exceed unity, as certain collision effects inside the device give rise to current multiplication; this phenomenon is being studied not only because it affects the design of transistors but also because it has certain practical applications.

It is possible for the reverse characteristics of a *p-n* junction diode to " run away " under certain conditions of temperature and reverse dissipation, and these conditions have been established. They are of great importance in connection with diode ratings at high ambient temperatures. The problems of series and parallel operation of EW54 diodes are now being considered in detail.

A silicon junction diode, type EW64, is being developed; this has a *p-n* junction of small area made by an alloy process, and is intended primarily for low current applications such as discriminator and diode " clamping " circuits. Silicon junction diodes have many uses because of their high reverse impedance and their ability to operate at higher temperatures than corresponding germanium devices. A typical silicon junction diode has a reverse impedance greater than 600 megohms at -60 volts and 20 deg. C., and at the same reverse voltage its impedance is still greater than 6 megohms at 100 deg. C. Unlike the germanium counterpart, it passes very little forward current at $+0{\cdot}5$ volt, but the current flow increases rapidly at higher voltages.

Type EW64 has a forward current greater than 50 mA at 1·2 volts, and withstands 100 mW dissipation at 20 deg. C. and 20 mW at 100 deg. C. The capacitance, which as in all other junction diodes varies inversely with the reverse voltage applied, is typically 3 *pF* at -9 volts. This diode is limited to a reverse working voltage of -60 volts, but other types are under development for higher reverse working voltages and greater power dissipation.

Research

This Section contains items from the Research Laboratories' programme which have not been covered elsewhere in this Progress article.

METALLURGY.

Powder Metallurgy of Titanium.

In the last few years the potential value of the light metal titanium has been recognised, and the rate of production is now increasing annually. The production of the metal from titanium tetrachloride leads to a material known as titanium "sponge", which can then be melted in an arc furnace to give solid metal. The production of titanium components by methods other than by melting and casting is, however, likely to be of value in particular applications. For example, the mass production of small titanium parts using powder metallurgy methods is an attractive possibility.

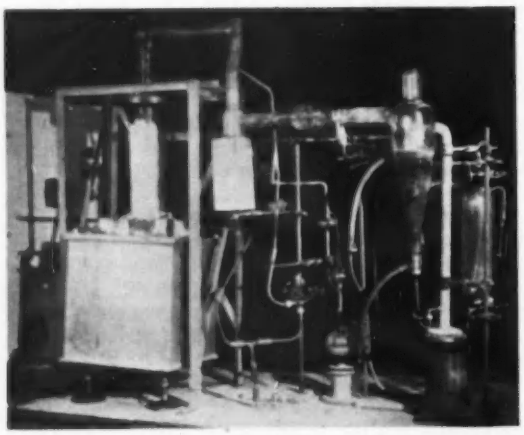


Fig. 110.—Apparatus used for treating titanium "sponge".

The reactive nature of titanium has made the preparation and handling of titanium powder difficult, but a simple method has now been developed for the preparation of uncontaminated powder from sponge. Titanium sponge is treated in purified hydrogen (fig. 110) to form titanium hydride which, unlike the metal, is brittle and may readily be crushed into a fine powder. This hydride powder may then either be reduced to the metal by heating in a vacuum or, preferably, the hydride powder itself can be pressed into compacts and the hydrogen driven off during a subsequent sintering operation.

The particle size of the powder is critical. If high-density sintered compacts are required on sintering, a fine powder should be used, but to minimise contamination by oxygen and nitrogen, the powder should be as coarse as possible. Using a powder with a surface area of 750 sq.cm./g., uncontaminated sintered compacts, with a residual porosity of less than 2 per cent. can be prepared (fig. 111).

Titanium alloys can also be prepared by this technique. The alloying elements can be added either as fine powders or as powders pre-alloyed with titanium.

Silicides of the Transition Metals.

Until quite recently little was known about the whole range of compounds formed between the element silicon and such metals as titanium and tungsten. These compounds, the silicides, have been the subject of a basic research programme and many of them have now been prepared and examined.

The silicides behave in many respects like metals, but resemble refractory compounds in that they are hard and brittle. Measurements of their heats of formation have been carried out and, from these data, some knowledge has been gained of the nature of the atomic bonding forces. Owing to the high melting points of many silicides and their good resistance to oxidation, these compounds are promising as high temperature materials, and the possible reactions between silicides and metals at elevated temperatures have therefore been investigated.

Although the silicides have little or no commercial value as yet, it is believed that applications, in which their unique properties will be put to good use, will be found within the next few years.

X-RAY DIFFRACTION INVESTIGATIONS.

The Oxide Cathode in Thermionic Valves.

X-ray diffraction has in the past yielded much fundamental information about the crystal structure of the alkaline earth oxide cathode. Many years ago, for example, it was established that solid solutions

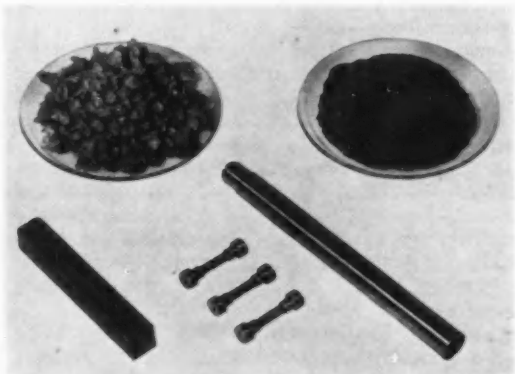
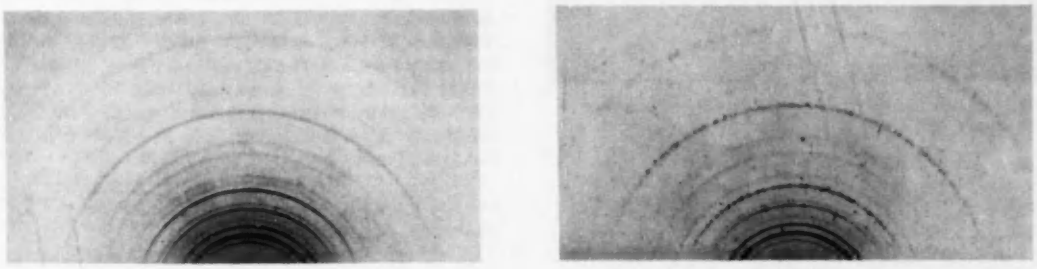


Fig. 111.—Titanium "sponge" powder and sintered products.

formed readily between the two basic constituent oxides of barium and strontium and that optimum performance was obtained when the molecular ratio was about 1:1. Not much was known, however, about the growth of the oxide crystallites on heating, although temperatures as high as 1100 deg. C. may be used in the processing and activation of a cathode. The development of the X-ray microbeam technique has enabled such growth to be examined.



(a) (b)

Fig. 112.—X-ray diffraction patterns of two oxide-coated cathodes, heated at 900 deg. C. (a) and 1,100 deg. C. (b) respectively.

The microbeam method (in which the beam is defined by a collimator 50μ [5 $\times$ 10^{-2} mm.] or less in diameter, as opposed to the more usual value of 0·5 mm.) leads to an improvement of resolution on the X-ray diffraction pattern so that " reflexions " from individual crystallites can be distinguished at a size of about 1μ and the pattern becomes " spotty ". As the size increases, " spottiness " becomes progressively more pronounced.

For purposes of X-ray study, experimental cathodes are coated with a paraffin wax to prevent any " weathering ", i.e. interaction with the atmosphere, of the oxide. Experiments have been carried out on the individual oxides of barium and strontium and on solid solutions It has been established that, under the usual conditions of processing, crystals develop in the size range 1 to 5μ. Patterns obtained with two cathodes, heated at 900 deg. C. and 1100 deg. C. respectively, are reproduced in fig. 112. The marked " spottiness " of the oxide rings after the treatment at 1100 deg. C. contrasts with the smooth continuous rings of the specimen treated at 900 deg. C. and shows that considerable crystallite growth in the oxide coating has taken place between these two temperatures.

With barium oxide cathodes it has been shown that too rapid heating of the carbonate raw material causes large crystals up to 50μ in size to grow. This completely ruins the thermionic performance. The excessive crystal growth is due to the fact that, when the temperature is raised rapidly, the carbonate melts before its decomposition to oxide is completed. The oxide crystals then grow in a flux of molten carbonate.

An unexpected observation emerged from supplementary measurements of the lattice dimensions. For both barium oxide and strontium oxide it was found that the measured structure-cell dimensions decreased as the temperature of heating *in vacuo* was increased. This effect has not yet been completely explained, but it is certain that such changes reflect profound disturbances of the crystal structure and an increase in lattice defects. These changes appear to be connected with the thermionic activation process.

Studies of the alkaline earth carbonates used as raw materials for the preparation of the oxide cathode have also shown interesting crystal growth phenomena resulting from heat treatment. In some varieties growth is limited by the particle size. In another variety, in which there is inevitably a small amount of sodium carbonate impurity, vigorous intercrystalline growth takes place above 600 deg. C. and " sintering " occurs. When crystalline growth is confined within the individual particles, " sintering " is not observed at any temperature to which the carbonate is likely to be subjected, and for some applications this is a very desirable property.

TELECOMMUNICATIONS MATERIALS.

Piezoelectric Crystals.

For the past two years, large crystals of synthetic quartz, suitable for the majority of oscillator uses, have been grown on a pilot scale. A potential disadvantage of this otherwise successful process is that the raw material is a cheap variety of rock crystal which still has to be imported from Brazil, the source of most of the piezoelectric-quality quartz used in the United Kingdom.

As a result of considerable research, methods have now been found by which quartz crystals of excellent quality may be grown entirely from native raw materials, such as flint and quartzites. The process can be made entirely independent of overseas supplies.

The trace impurities which affect the growth of quartz have been identified and, where necessary, the process can be modified to prevent the incorporation of these harmful impurities in the growing crystal. Fig. 113 shows such crystals grown from flint and quartzite compared with a crystal grown by the hitherto standard process.

Fig. 113.—Quartz crystals grown from flint and quartzite compared with a crystal grown by the earlier process.

Ferroelectric Materials.

Ceramic barium titanate materials have been developed for use as piezoelectric transducers in several applications, including those described on p. 55. Single crystals of barium titanate are now being grown, since they have advantages over ceramic materials in fundamental investigations into the nature of ferroelectricity and in applications based on hysteresis properties. These single crystals are grown from solution in molten potassium fluoride and develop the "butterfly" habit shown in fig. 114. The domain patterns are directly visible in polarised light, so that the effects of crystal imperfections, electrical fields and mechanical stresses on these patterns can be examined readily.

The search for new ceramic ferroelectric materials is continuing. For example, although neither sodium niobate nor cadmium niobate is ferroelectric at room temperature, sodium-cadmium niobates of suitable composition show ferroelectric properties. Indeed, these properties persist up to 200 deg. C, considerably above the limit of 120 deg. C. for barium titanate materials.

Near-Insulating Materials.

The work on "proper" semi-conductors is closely allied to a programme of research on materials which are more nearly insulators. The latter have the characteristic that they are transparent in at least part of the visible spectrum, whereas the semi-conductors are typically opaque in the visible spectrum and transparent only to infra-red radiation. The near-insulators are important as photoconductors under stimulation by visible light, as phosphors, as electron-emitting materials and as refractory insulators.

It has been found that the weak luminescence occurring in magnesium oxide under electron bombardment is enhanced by an electric field ; this effect corresponds with the "light amplifier" effect reported from America, and has stimulated research on field enhancement of luminescence in a variety of materials, including single crystals of several types of phosphor. The correlations between this effect, electro-luminescence and photoconductivity, are of great interest and are likely to lead to important advances in knowledge. Applications would be to television display and to the examination of X-ray images using fluorescent screens, where an intensification of the image would permit the use of smaller X-ray dosages.

The work on the effects of electron bombardment of various compounds has continued and has been extended to the types of phosphor materials used for cathode-ray tube screens. Here decomposition under bombardment would lead to a decrease in secondary emission and so indirectly to a decrease in light output from non-aluminised screens. It has been found that the stability is good both for pure phosphor materials and for magnesium oxide ; the mechanism of the small changes which do occur is under continued investigation.

Semi-Conductor Materials.

It is known that germanium junction transistors are sensitive to the atmosphere, especially to water vapour, and cannot be relied upon for stable operation unless hermetically sealed. An investigation

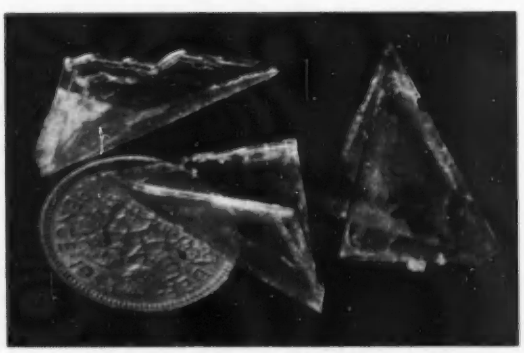


Fig. 114.—"Butterfly" habit of barium titanate single crystals grown from solution in molten potassium fluoride.

of the effect of the environment on the behaviour of a junction is therefore in progress. This work has shown that there is an ohmic conductance over the surface of a germanium crystal, stable with time, in parallel with a second conductance which grows with time after application of a reverse voltage to the junction. This second conductance is not ohmic, but shows a saturation effect with voltage such as is given by the junction itself. This is attributable to the growth of a region of *n*-type conductivity, from the junction, over the surface of the *p*-type region. The factors governing the growth of this undesirable surface layer are under investigation as a function of the state of the germanium surface, and of the type of ion adsorbed on it.

The electrical properties of semi-conductors alter with temperature, a factor which sets an upper limit

of about 70 deg. C. for the ambient temperature at which it is practical to employ germanium devices. Silicon, on the other hand, not only possesses good electrical characteristics but devices made from it are capable of operation at temperatures above 150 deg. C. This property thus opens up a complete range of applications in which germanium devices would function inefficiently, if at all.

Until recently, the chief obstacle to setting up a production unit for the manufacture of silicon devices (transistors, signal diodes and power rectifiers) has been the difficulty of producing large perfect single crystals of silicon with the desired electrical properties. This was due partly to the difficulty of purifying silicon to the required degree (about 1 part of impurity in 100 million parts of silicon) and partly to the formidable metallurgical difficulties in preparing large perfect single crystals.

These problems have now been studied in a research programme, during which several novel crystal-

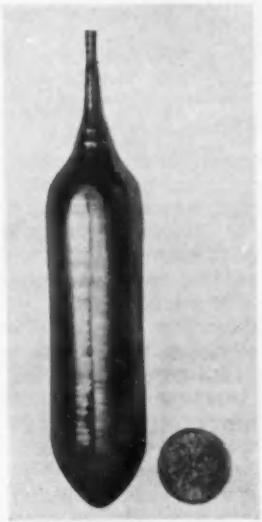


Fig. 115.—Perfect single crystal of silicon, weighing 100 grams.

growing techniques have been evolved. Fig. 115 shows a perfect single-crystal of silicon, weighing 100 grams, which possesses a uniform *n*-type resistivity of 20 ohm. cm. throughout its volume. One application of such material would be in silicon diodes with a high breakdown voltage.

SEMI-CONDUCTOR POWER RECTIFIERS.

Besides the many applications in electronic circuits for small semi-conductor devices, there is a considerable potential field of use, in power rectification, for diodes made with large-area slices of germanium or silicon. The attractions of these diodes arise chiefly from their compactness and high efficiency of rectification. An

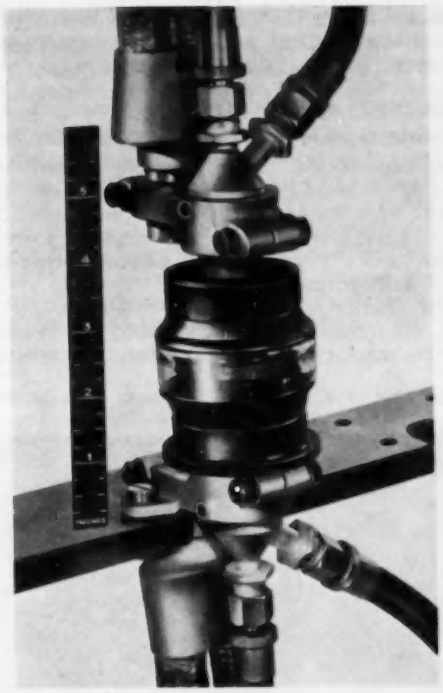


Fig. 116.—Experimental water-cooled germanium power diode.

experimental germanium power diode is shown in fig. 116. The *p-n* junction is mounted between a pair of substantial copper electrodes, both of which are water-cooled. The hermetically sealed glass-to-metal case around the junction prevents it from becoming contaminated. The characteristics of the

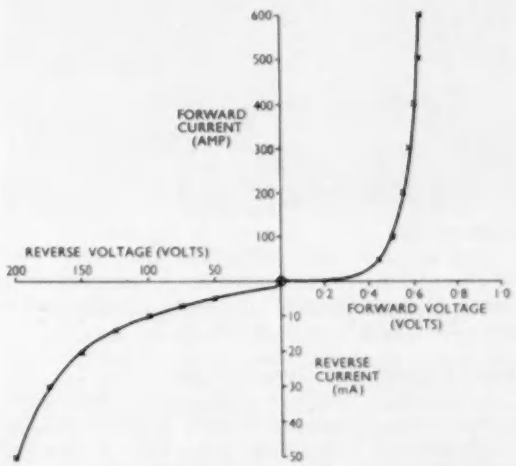


Fig. 117.—Characteristics of germanium power diode.

diode are shown in fig. 117. It has been operated successfully at mean rectified D.C. currents up to 300 amp.

TRANSISTOR APPLICATIONS.

Experimental Portable Broadcast Receiver.

An experimental battery portable receiver incorporating nine junction transistors and one point contact transistor has recently been constructed. The junction transistors used are of types EW52 (experimental) and EW59, and the point contact type is the EW51/C (experimental).

The receiver is 9½ in. × 8 in. × 4 in. in size (fig. 118), incorporates a 5 in. loudspeaker, and is tunable over the medium wave broadcast band. In general its

Fig. 118.—Experimental portable broadcast receiver, incorporating ten transistors.

performance compares very favourably with that of the average thermionic valve battery-operated portable receiver.

The frequency response is essentially level from 70 c/s to 4,000 c/s. The receiver has a maximum power output of about 400 mW, and an overall efficiency of more than 50 per cent. at this level.

Radio Interference Measuring Set.

A portable battery-operated radio interference measuring set having a frequency range of 160 kc/s to 285 kc/s has been constructed. This equipment is essentially a calibrated superheterodyne receiver having an intermediate frequency of 90 kc/s, and incorporates a total of seven point-contact transistors, six type GET1 and one type EW51 (fig. 119). The equipment includes its own standard 4 ft. rod aerial (fig. 120).

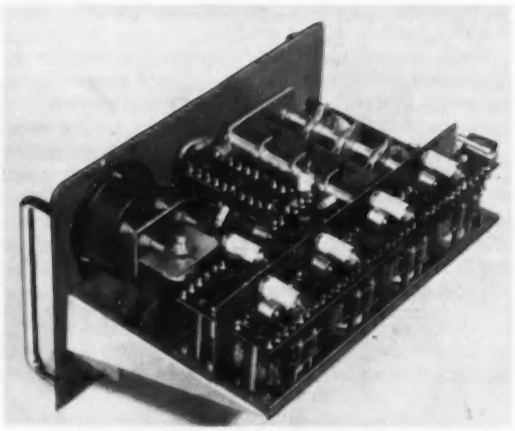


Fig. 119.—Radio interference measuring set, incorporating seven point-contact transistors.

The minimum signal at the input terminals which can be measured reliably is 1μV in 75 ohms, or 15μV in 15 kilohms, the measuring set being provided with alternative low and high impedance input circuits. The maximum error of measurement is less than ± 1 db. The total power consumption is only 440 milliwatts (22 mA. from a 20 volt battery).

This equipment was designed primarily for the purpose of measuring the harmonic radiations from the line time base of a television receiver, which fall within the long-wave broadcast band. The set also includes provision for monitoring on headphones the modulation components of a received signal, so that inter-

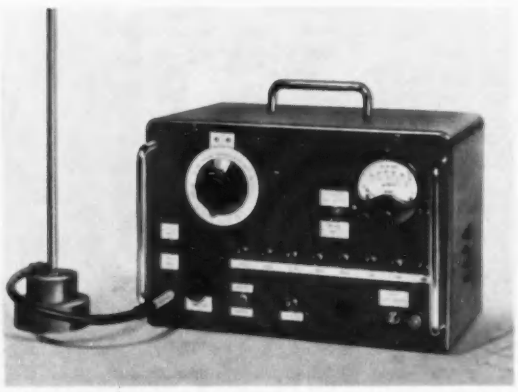


Fig. 120.—Radio interference measuring set with standard 4 ft. aerial.

ference signals may be clearly distinguished from broadcast stations.

The measuring set has the advantages of portability, robustness, longevity and very modest power requirements. A further important advantage over the usual mains-driven equipment is that, since the power supply is contained entirely within its case, there is no chance of errors due to radiation picked up by an external power lead.

WIDEBAND R.F. AMPLIFIER.

The improved high frequency performance of point-contact transistors has now made it possible to construct a compact wideband amplifier unit having a

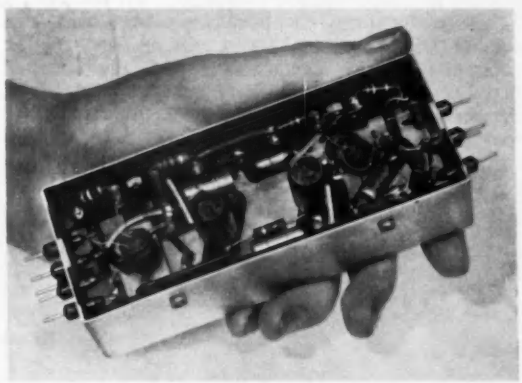


Fig. 121.—Wideband r.f. amplifier.

response flat to within $\pm$ 0·5 db. over a bandwidth of 3 Mc/s. The centre frequency is 5 Mc/s. The amplifier incorporates two experimental type EW51/B point contact transistors, and has a total power consumption of about 10 mA at 22½ volts. The gain of the amplifier between equal generator and load impedances of about 90 ohms is about 36 db. The overall dimensions of the amplifier unit, which is contained in a metal case to provide complete screening, is 4½ in. × 1¾ in. × 1⅜ in. (fig. 121).

Such a unit may, for example, be used as a line amplifier in a relay system conveying a carrier modulated with television signal information. It has the advantages of small size, robustness, long life and low power consumption, and yet provides sufficient gain at the frequencies quoted to balance the attenuation of about 1 mile of relay cable.

CATHODE-RAY TUBES.

The probability of colour television being introduced in this country depends largely on the solution of the problem of producing a colour display device which can be manufactured economically. Work has been done on various types of display devices, including those which have been established as being technically satisfactory. This work has covered investigations into the properties of colour phosphors, and the preparation of mosaic screens.

One method of producing colour pictures makes use of a mosaic screen, which consists of a total of approximately 6×10^5 phosphor dots of the three primary colours, red, green and blue. For a 21 in. cathode-ray tube, these phosphor dots are approximately 0·014 in. in diameter. In the completed tube, a shadow mask has to be located accurately in front of the mosaic screen. This mask has 2×10^5 apertures symmetrically arranged with respect to the phosphor dots, so that each of the beams from the three electron guns is allowed to pass through the apertures and excite only one of the three groups of colour phosphor dots.

LAMPS.

Among the fundamental researches into lamp problems has been a comprehensive theoretical and experimental study of the factors controlling the vaporisation and distribution of sodium in sodium lamps. This work has resulted in a lamp of new design and improved performance.

Fig. 122.—Schlieren photograph of G.E.C. high-bay unit, showing heat flow through drip-proof canopy.

The complex problem of dimming fluorescent discharge lamps has been studied theoretically. This has led to a relatively simple procedure for the design and planning of individual dimming installations (p. 58).

Although the discovery of new phosphors often arises empirically from trial combinations of likely matrices and activators, the improvement of existing phosphors calls for a deeper study of the effects of, for example, crystal structure, purity, and particle size on

the starting materials and finished product. The improved efficiency of fluorescent lamps, and the excellent temperature stability of the new triple-silicate phosphors used in fluorescent high pressure mercury lamps, mentioned earlier, are largely due to studies of this type.

Equally, an essential part in the improvement of capacitors is the study of the part played by impurities in modifying the electrical and mechanical properties of impregnants.

A study of the spurious oscillations at television frequencies in vacuum filament lamps has indicated that these are of the Barkhausen-Kurz type. Changes in structural design have been an important factor in reducing the intensity of the oscillations to a negligible value in certain important classes of vacuum lamp.

ILLUMINATION.

The study of thermal problems is vitally important in the design of lighting equipment, and the apparatus used for this purpose in the Illumination Laboratory has recently been completely re-built*. The two main pieces of apparatus are the temperature-measuring gear, and the Schlieren apparatus for studying convection streams around lighting equipment.

Temperatures are recorded with very thin thermocouples of selected wires and strips, specially bound with glass-silk insulation to form a twin-cable. These thermocouples are attached to the fitting under test which is mounted in a double-walled enclosure to exclude draughts. Associated apparatus includes electric arc welders based on designs from the National Physical Laboratory, suitable for making the junctions, and a comprehensive equipment for calibration. Specially designed thermocouple holders are available for surface temperature measurements, as well as temperature sensitive paints and crayons.

A study of the flow of convection currents is important in many thermal problems. To this end, a Schlieren apparatus has been built by which convection current around apparatus in one of the enclosures can be made visible and photographed (fig. 122). The optical train is a development of one devised in the Laboratories in 1933; it provides for four presentations, some in colour, of differing sensitivities and characteristics. The apparatus is very rigid and stable and is easily adjusted.

* H. F. Stephenson: "The Measurement of Temperature in Lighting Equipment", *Light and Lighting*, Vol. 47, No. 12, pp. 369-372, December, 1954.